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Agriculture in Its Relations to Bacteria and Other Ferments.

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It is rather difficult to come before a city audience with a purely agricultural subject. A few years ago it was difficult to address farmers on such a subject as I have to take up to-night. They knew nothing of how plant-foods were prepared, and especially of the relation of ferments to agricultural industries. Even at the present time we are prone to look upon bacteria and other ferments as the enemies of mankind; yet if the facts were well known nearly all the organisms which we look upon as our enemies would be regarded as our best friends.

Especially do the processes of fermentation lie at the very foundation of plant and animal life. Without fermentation, the organic food which contains the elements of

*A lecture delivered before the Franklin Institute, Friday evening, November 1, 1901.

plant-nutrition would never be reduced to a condition in which the plant could assimilate it. Without fermentation, the great œnological industries of wine-making, beer-making and cider-making would be impossible. Butter and cheese would have no flavor, and, in general, the world would become stagnant and dead. It is true that there are a few pathogenic germs which produce disaster and even death, but if we could have our desires and bring death to all germ-life, we would destroy agriculture and thus the human race.

Agriculture is the basic industry, because without it all others would be impossible. The world might do without steel, without steam and without sterilization, but it could not exist without bread and meat. To paralyze the agricultural industries of the world for a single year would bring famine and death to almost the whole human race. In other words, the stores of foods and other agricultural products necessary to life which are carried over from one year's end to another would not be sufficient to carry the human race through a single season of agricultural disaster. Hence, even those living in cities are beginning to understand the importance of agriculture and to know that while it is the oldest art it is almost the newest science.

What I wish to take up principally to-night are those ferments of a bacterial nature, which, living in the soil and in symbiosis with certain plants, are capable of preparing organic food that plants may eat it. Formerly, the soil was regarded as mineral matter, simply decayed rocks mixed with dead organic material. Now we know that the soil is a living organism whose life is as important as that of the animal or the plant itself. If the soil be killed it is absolutely sterile. In other words, if the living organisms which make soil fertile are destroyed, the soil is incapable of producing a crop. Plants as a rule eat only mineral food, such as phosphoric acid, potash and nitric acid, but animals, usually, eat only organic foods, such as fats, sugars and protein matter. Plants cannot be fertilized with fats or sugars or with protein matter, but the nitrogen which the protein contains is the most important element of plant-food

and it is only through bacterial or fermentative action that this nitrogen is converted into nitric acid, in which form alone the plant can consume it.

Agricultural chemistry has developed what is now a well-known fact, that plants are pre-eminently eaters of mineral matters. Through the plant the mineral matter is changed in its structure, passing into organic forms of combination in which alone food can nourish animal life. Nitrogen is one of the chief elements of plant-food, but in the inert state in which it exists in the atmosphere it is of no digestive value whatever. A plant will speedily starve and die for lack of nitrogen in an atmosphere four-fifths of which are composed of that gas. In like manner a plant would wither and die if fed unlimited quantities of nitrogen in an organic state of combination, or even as ammonia, in any of its compounds. With the exception of a few unimportant cases, the plant can only eat nitrogen when it is presented in the form of nitric acid or of a nitrate of some kind, such, for instance, as the nitrate of soda.

The term nitrification, therefore, is applied generally to the whole process, by means of which free nitrogen or any organic or inorganic compound of nitrogen reaches the state of nitric acid.

This definition shows at once that the process includes two general types :

(1) The conversion of nitrogen, existing free or in inorganic compounds, into nitric acid.

(2) The conversion of organic nitrogen into nitric acid.

The decay of organic matter containing nitrogen is due to the activity of certain living organisms of a bacterial nature, through whose vital functions the destruction of the organic matter is accomplished. The first tendency in the destruction of organic matter is its resolution into other compounds less complex, and the final tendency is the resolution of organic compounds into the original elements.

Since we are concerned at the present time only with nitrogen, we find that in the process of decay the nitrogen may exist in a large number of different combinations and, when the process is carried to its ultimate end, free nitrogen

may result. For the particular purpose of this paper, we may say that the nitrifying process in organic matter is accomplished in three great stages, namely:

(1) The conversion of the organic compounds into ammonia or compounds of ammonia.

(2) The conversion of ammonia into nitrous acid or compounds of nitrous acid.

(3) The conversion of the nitrous acid into nitric acid or compounds of nitric acid.

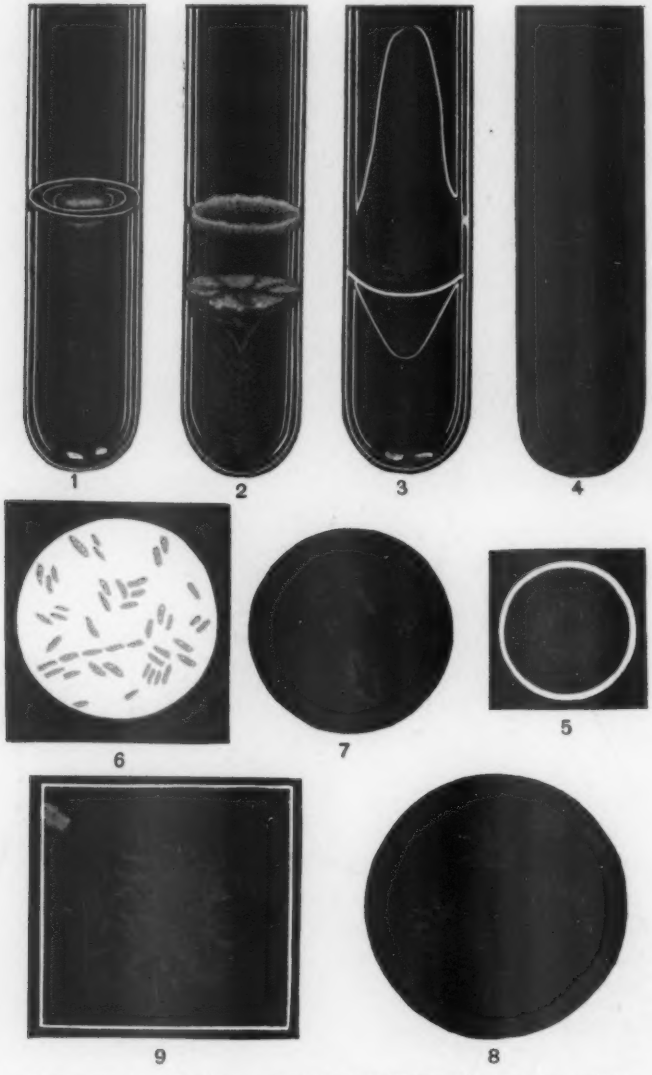
Each of these processes is accomplished by a distinct species of organisms, each species being suited only to its own work and being incapable of accomplishing the work of others. Thus it happens that if only the organisms capable of producing ammonia be present, the process of decomposition stops at the first step; and if only those capable of producing ammonia and nitrous acid be present, it stops at the second step; whereas, if all three families of organisms be present, the process is completed with the formation of nitric acid.

If we go further and produce free nitrogen, the process is no longer properly called nitrification but denitrification.

It is evident, from the standpoint of agriculture, that the best results are accomplished when nitric acid is produced. The presence of denitrifying organisms, therefore, must be regarded as inimical to agricultural interests.

I will now show, by projections upon the screen, the organisms of the three classes which have been mentioned. (The lecturer projected upon the screen micro-photographs of the organisms producing the three types of nitrification mentioned.) The organisms producing ammonia are more numerous, while those forming nitrous and nitric acids are few in number, in fact only one well-defined species of each kind is known to exist. The nitrous organisms are much larger than the nitric organisms and these two are intimately related, but one is not capable of performing the functions of the other.

The most important of the organisms developing ammonia from organic matter is the *bacillus mycoides*. The colored plate representing the different stages of develop-



FIGS. 1 TO 9.—*Bacillus mycoides* and illustrations of its activity.
SIP. fecit.

ment and activity of the *bacillus mycoides* has been adopted from Volume X, the first part of "Bacteriological Diagnostik" by Lehmann, Table 4.

Fig. 1 represents the appearance of the gelatine culture in a test-tube on the fourth day, of a temperature of 22°.

Fig. 2 the same on the fourteenth day.

Fig. 3 represents the culture in agar agar two days old.

Fig. 4, agar-agar culture, eight days.

Fig. 5 represents the upper surface of the culture on the eighth day.

Fig. 6 represents a pure culture of the bacillus mycoides stained.

Fig. 7 represents a culture on an agar plate at the end of the first day, natural size.

Fig. 8 represents the culture on an agar plate, four days old, natural size.

Fig. 9 represents a culture on a gelatine plate on the fourth day, natural size.

The following description of the *bacillus mycoides* is taken from Wiley's "Principles and Practice of Agricultural Analysis," Volume I, page 464:

"*Bacillus mycoides* is the most active of these organisms. It occurs constantly in surface soils and is present in the air and in natural waters. In decomposing albumin it produces a strong alkaline solution due to ammonium carbonate. Organic carbon, during this process, is converted chiefly into carbon dioxide, but small quantities of formic, propionic and butyric acids are also produced. Any organic sulphur which is present is converted into acid. No hydrogen or nitrogen is eliminated in a free state. While slight alkalinity is favorable to the development of this bacterium, yet it may be propagated in a feeble sulphuric acid solution when the acid is less than 1 per cent.

"The greatest activity of this organism is manifested at 30°. Below 5° and above 42° no ammonia is produced. The bacillus will not develop in an atmosphere of hydrogen or carbon dioxide, except in solutions of organic matter and nitrate. In addition to its action on egg albumin, it decomposes other proteid bodies as well as leucin, tyrosin, creatin

and asparagin. It, however, does not oxidize urea, nor does it develop in solutions of ammonia salts and nitrates, except as mentioned above. When soluble carbohydrates are present, acids are formed. It is concluded from these experiments that the final oxidation of organic nitrogenous matter is preceded by its conversion into ammonia carbonate."

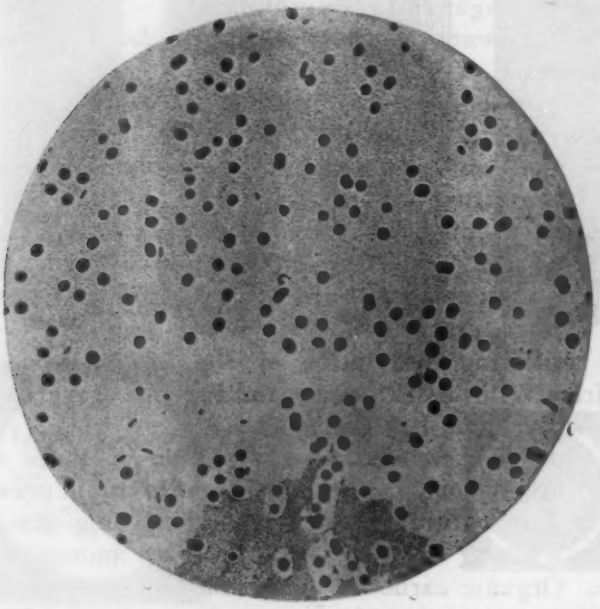


FIG. 10.—Nitrous ferment prepared by Winogradsky from soil from Cito.

CONVERSION OF AMMONIA INTO NITROUS ACID.

So far as is known, there is only one species of bacteria which has the power to convert ammonia into nitrous acid. This bacterium has been isolated independently both by Warrington and Winogradsky.

These bacteria are practically alike in all soils, but in some soils they seem to be more active than in others, so that it may be necessary to distinguish some minor differences in specific qualities.

The whole group of bacteria active in changing ammonia into nitric acid may be described as nitro-bacteria. The one

converting ammonia into nitrous acid is known as nitrosomonas, and the group converting nitrous into nitric acid is known as nitro-bactere.

The nitrous ferment is much larger and apparently more vigorous than the nitric ferment. The illustrations of the groups are taken from Wiley's "Principles and Practice of Agricultural Analysis," Volume I, facing page 480. They are due to Winogradsky.

FIG. 11.—Nitric ferment prepared by Winogradsky from soil from Cito.

The second type of nitrification to which attention has been called is that process by means of which the atmospheric nitrogen is converted into forms suitable for plant-food. It is well known that combustion, electrical discharges and some natural forces are capable of converting a small quantity of nitrogen into nitric acid. The amount thus converted is not inconsiderable from an agricultural standpoint, and large quantities of nitrogenous plant-food annually reach the surface of the earth in rain-water.

More important to agriculture are the possibilities of the nitrifying organism acting directly upon atmospheric nitrogen. These organisms do not exist to a very large degree in a free state but are found in symbiotic union with a certain family of plants.

In so far as is definitely known, the leguminosae, that is, the family to which clover, peas, beans and similar plants

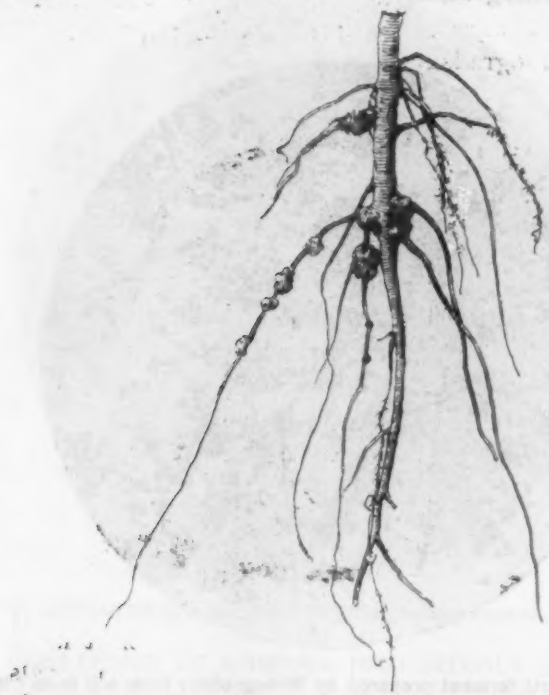


FIG. 12. Roots of Yellow Luzerne showing the nodules in which live the bacteria capable of oxydizing free nitrogen. *Drawn from Photograph by S. I. P.*

belong, are the only plants capable of supporting the parasitic life of these nitrifying bacteria. From time immemorial it had been noticed that such plants often had small nodules on their roots from the size of a shot to the size of a pea. These were formerly supposed to be evidences of a diseased condition. Some ten years ago it was discovered that these nodules were inhabited by bacteria which have

the faculty of converting free nitrogen into forms suitable for plant-nutrition. Thus, what was supposed to be the effect of a disease is found in fact to be a most useful form of bacteria.

Many attempts have been made to induce these bacteria to grow upon the rootlets of other plants, but so far without success. In the light of this knowledge we are able to explain the phenomenon which has long been known to exist, namely, that by the growth of clover, peas and beans, and by plowing this growth into the soil, the fertility of the soil can be increased. We see now that this increase of fertility is due to the fixation of atmospheric nitrogen, and thus there is offered to the scientific farmer a way of enriching his soil at the expense of the atmosphere itself.

A characteristic illustration of the attachment of these bacteria to the roots of a leguminous plant is shown in *Fig. 12.*

The discovery of the existence of these organisms has led to systematic cultures with a view to supplying them to soils which are deficient in them. The commercial name which is applied to these cultures ready for distribution is nitragin.

These cultures are supplied in small phials or bottles and are prepared by adding them to a mass of moist rich earth, which is frequently stirred to promote the multiplication of the organisms throughout the whole mass. When they have multiplied sufficiently, the mass of earth containing them is scattered over the fields in which it is desired to introduce the organisms. The organisms may also be suspended in water with which the seeds of the leguminosae are sprinkled, and thus the organisms are carried directly into the soil with the seed.

Experience has shown that these organisms developed on the rootlets of one kind of leguminosae are not well suited to the growth of other kinds. For instance, the organism developed on peas and beans do not do well with clover, and vice versa. Thus it is necessary to state upon the package the character of the group to which the nitragin is adapted.

Numerous experimental cultures have shown the utility of these organisms, but their application in field culture has not been so successful. The laws which govern the distribution and multiplication of these organisms in the field, and the best methods of attaching them directly to the rootlets of the plants, are not fully developed. There is every reason to believe, however, in view of all that has been accomplished, that the future will see a systematic and successful method of applying root bacteria in the development of all forms of leguminous plants.

Soil bacteria, which it is claimed are useful in general agriculture, have also been propagated by cultures, and likewise placed upon the market. One species of these bacteria is known as alinite. Alinite is claimed to be a germ through the activity of which free nitrogen enters into chemical combination in a form especially adapted to the nourishment of cereals. The process of manufacture is covered by patents. The product is a brownish yellow amorphous powder which is usually delivered in a sealed yellow glass tube accompanied with directions for its use.

[*To be concluded.*]

ARTIFICIAL ABRASIVES.

In the volume of the Mineral Resources of the United States, 1901, about to appear, Dr. Jos. Hyde Pratt (U. S. Geological Survey) makes the following references to the production of artificial abrasives:

"The experiments in producing artificial abrasives that have been in progress during the last fifteen years have met with success, and there are now three artificial abrasives on the market—carborundum, crushed steel and artificial corundum. Carborundum is produced by the Carborundum Company at Niagara Falls, and in 1901 the total production of carborundum was 3,838,175 pounds, valued at from 8 to 10 cents per pound, as compared with 2,401,000 pounds in 1900. Carborundum is now used to a certain extent as a general abrasive. Crushed steel is used in the stone-cutting trade, particularly by the marble and granite cutters. The production of crushed steel by the Pittsburg Crushed Steel Company in 1901, amounted to 690,000 pounds, being 10,000 pounds less than the production of 1900. A new industry has been started in the manufacture of artificial corundum. The Norton Emery Wheel Company has erected a plant at Niagara Falls for the manufacture of artificial corundum, and already two or three carloads of the material have been manufactured and made into wheels, etc., which are reported as giving good satisfaction."

Equilibrium of Iron-Carbon Systems.*

By G. Charpy and L. Grenet.

M. Bakhuis Roozeboom gave in 1900† an interpretation of known facts relative to the constitution of metals formed of iron and carbon, which is unexceptionable from a theoretical point of view, but upon which some points remain doubtful on account of insufficiency of exact experiment. In particular, the conditions in which M. Roozeboom admits that carbon separates under the form of graphite in white-iron castings submitted to annealing have appeared to be contradictory to a certain number of facts previously observed in the manufacture of malleable-iron castings. Messrs. Le Chatelier and Stansfield have raised some objections on this point, and cited some experiments of Royston, Mannesman, etc., according to which the separation of graphite conforms to a diagram notably different from that adopted by M. Roozeboom. In these experiments, made on a practical point of view, account has not been taken of substances other than the carbon contained in the castings; notwithstanding, certain substances, silicon, manganese, etc., have an incontestable influence on the separation of graphite. One can believe then, as appears to be admitted by Mr. Hugh P. Tiemann, in a work recently published,‡ that the abundant separation of graphite observed by M. Royston was due to the presence of silicon in the castings employed.

We have made a large number of experiments on this point of view; we note, in particular, the results obtained

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*Translated from *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 31 Mars, 1902, by A. E. Outerbridge, Jr.

†H. W. Backhuis Roozeboom. Iron and steel from the point of view of phases. *Bulletin de la Société d'Encouragement*, Novembre, 1900.

‡Hugh P. Tiemann. The temperature limits for the separation of graphite from martensite in pure cast-iron. *The Metallographist*, October, 1901.

on five castings containing practically the same amount of total carbon, and in which the other elements exist in small quantities, except silicon, which is in variable proportions.

The following table gives the composition of the castings:

TABLE I.

	Carbon.	Silicon.	Manganese	Sulphur.	Phosphorus.
No. 1 . . .	3·60	0·07	0·03	0·01	traces
" 2 . . .	3·40	0·27	traces	0·02	0·02
" 3 . . .	3·25	0·80	traces	0·02	0·03
" 4 . . .	3·20	1·25	0·12	0·01	0·01
" 5 . . .	3·30	2·10	0·12	0·03	0·01

The castings had been poured into cold water and did not contain any appreciable quantity of graphite, except the last, where there was found 0·20 per cent.

Some fragments of these castings were subjected to annealing more or less prolonged at various temperatures; these temperatures were obtained either by continuous increase or by decreasing, after having attained a temperature more elevated; in each case the operation was terminated by quenching in cold water. In the specimens thus treated, we determined the total carbon and graphitic carbon, the difference giving the combined carbon.

The graphite was determined by the process indicated by Ledebur dissolving the metal in nitric acid of the density of 1·18 and burning in oxygen the insoluble residue remaining after boiling one hour.

It does not appear to us useless to specify that what we call graphite in this work, according to custom in metallurgical researches, is the residue of carbon insoluble in nitric acid. We determined in each case also the silicon.

From all these tests we can deduce the following results relative to the separation of graphitic carbon by annealing. We give, in each example, the percentages observed of graphite and of combined carbon, of which the sum total is not rigorously constant for each specimen. It is necessary, therefore, to take account of the values of both these figures

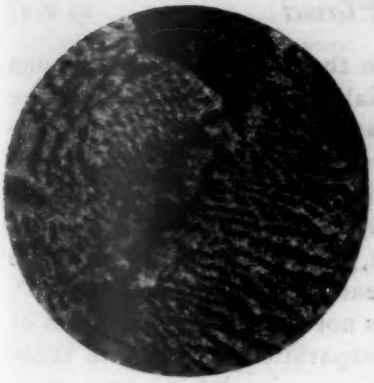


FIG. 1—White iron.

FIG. 2—Casting No. 2. Heated to 1000° (simply polished).

FIG. 3—Casting No. 3. Heated to 1000° (simply polished).

FIG. 4—Casting No. 5. Heated to 1000° (simply polished).

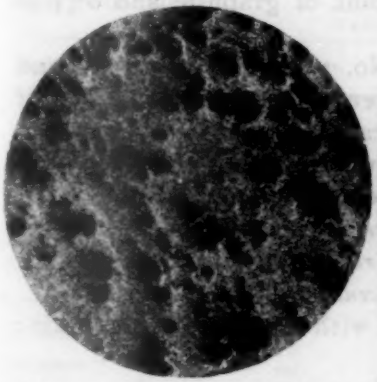


FIG. 5—Casting No. 5. Heated to 800° (simply polished.)

FIG. 6—Ferrite and graphite.

in order to be able to eliminate the influence of variations of carbon, either due to a partial decarburation during the annealing or to some irregularities of composition in the ingot, which we have thought necessary to correct.

(1) *The separation of graphite is induced at a lower temperature according as the percentage of silicon is greater.*

Thus, for the casting No. 1, which contains only some traces of silicon, a prolonged heat at a temperature of 1,100°, or at a lower temperature, does not cause any separation of graphite. But, at 1,150°, the separation of graphite takes place.

In the casting No. 2, after heating four hours at 700°, 800°, 900° and 1,000°, we observe no trace of graphite, but the graphite appears after heating to 1,100°.

In the casting No. 3, the graphite appears as traces after heating to 800°.

In the castings Nos. 4 and 5, a temperature of 650° is sufficient to separate carbon. In the last, in particular, after heating for six hours at 650° the proportion of graphite increased from 0·10 to 2·83 per cent.

(2) *The separation of graphite, once having commenced, continues at temperatures lower than that which induced the reaction.*

Thus, a small piece of casting No. 1 heated to 1,170° and quenched, contained only 0·50 graphite and 2·61 of combined carbon. Another fragment of the same casting, heated for the same time to 1,170° and cooled slowly to 700°, then quenched, contained 1·87 per cent. of graphite and 0·43 of combined carbon.

Likewise, a fragment of No. 3, heated to 1,170° and quenched, contained 1·42 per cent. of graphite and 1·69 of combined carbon. Another fragment heated to 1,170° and cooled slowly to 700°, then quenched, contained 2·56 per cent. of graphite and 0·38 per cent. of combined carbon.

(3) *At a constant temperature the separation of graphite is effected progressively at a slower rate of speed according as the temperature is lower and the percentage of silicon is less.*

Thus, for the casting No. 3, with 0·80 silicon, we obtain:

TABLE II.

Period of Heating.	Temperature.	Graphite.	Combined Carbon.
	deg.		
One hour	800	0·10	3·19
Four hours	800	0·22	3·07
One hour	900	0·30	2·97
Two hours . . .	900	0·60	2·40
Four hours	900	1·58	1·14
One hour	1000	0·37	2·94
Two hours	1000	1·50	1·41
Four hours . .	1000	1·47	1·29

The following are some figures relative to casting No. 4 with 1·20 per cent. silicon:

TABLE III.

Period of Heating.	Temperature.	Graphite.	Combined Carbon.
	deg.		
One hour	700	0·06	3·42
Two hours	700	0·21	3·30
Four hours	700	0·20	3·13
One hour	800	0.12	3·18
Two hours	800	0·51	2·47
Four hours	800	1·64	1·56
One hour	900	2·28	0·90
Two hours	900	2·32	0·90
Four hours	900	2·35	0·99

Finally, the following figures relate to casting No. 5 with 2 per cent. silicon:

TABLE IV.

Period of Heating.	Temperature.	Graphite.	Combined Carbon.
	deg.		
One hour	700	1·39	1·90
Two hours	700	2·09	1·19
Four hours	700	2·67	0·28
One hour	800	2·36	0·78
Two hours	800	2·31	0·89
Four hours	800	2·43	0·54
One hour	900	2·33	0·88
Two hours	900	2·32	0·90
Four hours	900	2·33	0·90

We observe that for the last casting, the equilibrium is attained at the end of one hour at 900°, since the percentage of graphite does not vary on prolonging the time of heating to four hours. In the casting No. 3, with 0·80 silicon, the equilibrium is far from being attained at the end of four hours at the same temperature. For castings lower in silicon the phenomenon is not so clearly observable, because the transformation is not induced at temperatures lower than 1,100°, in spite of prolonged heating.

(4) *The percentage of combined carbon which corresponds to the equilibrium at a given temperature diminishes as the percentage of silicon increases.*

The following table gives the figures observed after four hours heating at different temperatures. For castings Nos. 1 and 2 we have induced the reaction by first heating to 1,150° and 1,100°, and cooling slowly to a given temperature.

TABLE V.

Samples.	To 1100 Deg.		To 1000 Deg.		To 900 Deg.		To 700 Deg.	
	Graphite.	Combined Carbon.	Graphite.	Combined Carbon.	Graphite.	Combined Carbon.	Graphite.	Combined Carbon.
No. 1 . . .	1·15	1·74	1·03	1·74	—	—	1·87	0·43
" 2 . . .	1·26	1·93	1·00	1·62	—	—	—	—
" 3 . . .	1·61	1·26	1·60	1·52	1·67	1·17	2·56	0·38
" 4 . . .	2·10	1·02	2·20	0·98	2·32	0·90	—	—
" 5 . . .	2·18	1·00	2·10	0·93	2·33	0·90	2·67	0·28

(5) *The percentage of combined carbon which corresponds to the equilibrium is diminished as the temperature is decreased.*

The figures already cited indicate this diminution; we will give, moreover, the results obtained in two series of experiments in which we have sought to approach as closely as possible the state of equilibrium.

For that purpose, specimens of castings 1 and 3, surrounded by pulverized wood-charcoal have been heated to 1,170°, then cooled very slowly at about 50° per hour to

different temperatures; we maintained these temperatures for two hours and then quenched. For temperatures below 900° the operations lasting more than one day have been made many times; that is to say, they have been arrested at 900° and allowed to cool, then on the following day reheated to 900° and again cooled slowly. We obtained the following results:

TABLE VI.

Temperatures.	Sample No. 1.		Sample No. 3.	
	Graphite.	Combined Carbon.	Graphite.	Combined Carbon.
deg.				
1170	0·50	2·61	1·42	1·69
1100	1·15	1·74	1·49	1·48
1000	1·03	1·74	1·35	1·55
900	—	—	1·91	0·99
800	1·15	1·31	2·09	0·43
700	1·87	0·43	2·36	0·38

The microscopic examination of many treated specimens confirms the results of chemical analysis, without adding much information. In the original state the castings present all the known aspects of white-iron castings.

The *Fig. 1* reproduces one of these specimens; the white parts corresponding to cementite, the dark parts to martensite. When we anneal at different temperatures the castings deprived of silicon, we modify the respective dimensions of these elements and cause variation in the concentration of the martensite following the laws already known.

In the castings containing silicon, we see, moreover, the graphite becomes readily visible by simple polishing, without etching with chemicals. The aspect of the separated graphite varies with the temperature of separation, and with the content of silicon. We give here some micro-photographs.

When we examine certain specimens in which we have sought to obtain the equilibrum at low temperatures, we recognize that the transformation is more advanced in cer-

tain regions where the graphite is found directly in contact with the ferrite.*

In *Fig. 6* is given an example obtained from casting No. 1, which contains only a trace of silicon. It is probable that these regions are those in which the transformation is complete, consequently, the stable condition, when cold, of the iron-carbon systems corresponds to the co-existence of two phases—pure iron and graphite; all the other forms in iron and steel, and notably cementite being unstable at a low temperature. The case of iron-carbon systems resembles somewhat that of phosphorus, for which the stable form, when cold, is red phosphorus, but that which we

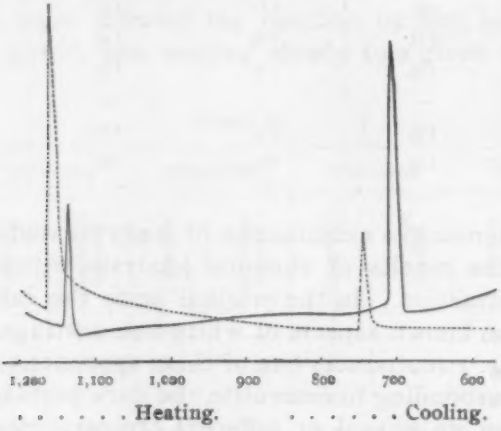


FIG. 7.

obtain and utilize most frequently is the unstable form of white phosphorus.

We have also determined the *critical points* of castings studied by the pyrometric method. For the different castings we have always observed two critical points very clearly, practically at the same temperatures. The first which is produced at about 700° corresponds to the resolution of pearlite. It is too well known to require space for argu-

* M. Osmond has already shown a case in which he observed the ferrite in contact with graphite. *Bulletin de la Société d'Encouragement*, Nov. 30 1900, page 657.

ment. The second is observed at about 1,150°; it is extremely sharply defined, as indicated in *Fig.* 7, which reproduces the heating and cooling curves observed with a casting low in silicon. It is produced under the same conditions with the castings high or low in silicon.

The following table indicates the temperatures at which it has been observed for the various castings:

TABLE VII.

Sample.	Heating.	Cooling.
No. 1	1140	1120
No. 2	1165	1145
No. 3	1137	1130
No. 4	1165	1137
No. 5	1165	1145

It has not been possible for us to determine whether this critical point corresponds to the resolution of mixed martensite-graphite eutectic, or to that of mixed martensite-cementite eutectic. Possibly there is a mingling together of these two transformations, which would be a much nearer approach than is indicated in the Roozeboom diagram.

One peculiarity interesting to note, is that the critical point of 1,150° in all these castings is much more accentuated in the heating than in the cooling. It is the reverse of that which we observe ordinarily for the critical points.

The observations contained in this note indicate already that a certain number of points in the diagram of Roozeboom should be modified, but it seems necessary to have still other experiments before proposing a new diagram.

FORMATION OF NATURAL PARAFFINS.

Numerous theories have been put forward at different times to account for the formation of natural parraffins, the one received with most favor being that due to Berthelot and developed by Mendeléeff, in which the action of steam upon metallic carbides was regarded as the main source of the hydrocarbons. The chief stumbling block to this view was the difficulty of explaining the mode of formation of the naphthenes of the Russian oilfields. The researches of MM. Paul Sabatier and J. B Senderens on the action of reduced nickel, iron and other metals upon hydrocarbons have now placed the "chemical" theory of petroleum formation on a firm experimental basis. By the direct hydrogenation of acetylene in the presence of nickel they have obtained liquid mixtures of hydrocarbons which can be made to correspond either with American or Caucasian petroleum by varying the conditions of the experiment. To account for the formation of petroleum it is thus sufficient to admit that there are in the depths of the earth free alkali metals and metallic carbides, which in contact with water give rise to mixtures of hydrogen and hydrocarbons. These gases encounter nickel, cobalt or iron in a finely divided state, and thus give rise to the mixtures of hydrocarbons forming natural petroleum.—*London Nature.*

THE RAILROADS OF THE WORLD.

The *Archiv für Eisenbahnwesen*, which has now for many years published statistics of mileage of the railroads of all countries in the world with some other data, says the *Railroad Gazette*, gives a somewhat more extended review in its last number, in which the figures are brought up to 1900, and so make a record of the work of the last century. The mileage built in each decade has been for the world:

1830–40	4,772	1870–80	101,081
1840–50	19,198	1880–90	152,179
1850–60	43,160	1890–1900	107,421
1860–70	63,255		

The mileage built before 1830, insignificant in amount, is included with the 4,772 miles credited above to the decade, 1830-40.

Of the total of 491,066 miles completed at the end of the century, more than one-half had been built since 1880 and nearly three-fourths since 1870. The total built in the forty years down to 1870 (130,385 miles) was one-seventh less than the construction in the single decade ending with 1890. It is noticeable, however, that in the last decade of the century 44,758 miles less were built than in the preceding ten years. This is one of the indications that the civilized and productive industrial countries of the world are now generally well equipped with these instruments of transportation. Europe (except Russia) and North America have immediate need of no large additions to their mileage. There is still abundant room for railroads in Asia, Africa and South America, but the slow growth of industries on these continents, two of which are over rather than under populated, but whose population is to a great extent a bar to progress such as Europe and North America have had in the past century, gives no promise of rapid railroad extension.

Note on Some Experiments with a New Form of Pressure Regulator.*

By William Kendrick Hatt, C.E., Ph.D.
Professor of Applied Mechanics, Purdue University.

General.—The writer here records some experiments which were made under his direction in the Engineering Laboratory of Purdue University on a new apparatus by Mr. Will Hull, of the Class of 1901, who developed the details of the apparatus at the suggestion of Mr. J. T. Wilkin, Engineer for the Connersville Blower Company, Connersville, Ind.

The apparatus (*Fig. 1*) consists essentially of an expanding nozzle and a flat circular disc, against which the jet from the nozzle is directed, the disc being enclosed in a suitable chamber. The action is similar to that of the well-known ball nozzle, and the disc replaces the ball. In case of the ball nozzle the back pressure forcing the ball against the jet is the pressure of the atmosphere. In the apparatus the disc is enclosed in a chamber, and the back pressure is the pressure of the water in the chamber. This pressure is greater than that in the rapidly moving sheet of water on the upstream face of the disc, so that the disc moves toward the nozzle until equilibrium is established. The disc thus automatically throttles the upstream.

When this apparatus is inserted in a pipe line the pressure on the down-stream face of the disc is preserved fairly constant (within the limits of the experiments and for certain range of pressure in case of the apparatus used) while the upstream pressure varies within wide limits. The principle of the apparatus will have an application whenever it is desired to deliver water at a constant pressure to a machine from a source of supply subject to fluctuations of pressure. Whether a design of disc and nozzle could be

* Read before Indiana Academy of Sciences, January 27, 1902

reached which would regulate pressure in case of air or steam is not determined.

The experiments were initiated with the desire to obtain information which would serve as a basis for proportioning this apparatus to serve various conditions of pressure and delivery. The experiments were interrupted before that point was reached. The results obtained with the apparatus are generally interesting, and it seems worth while to record them.

Mr. Hull used various combinations of disc and nozzle until he found the proper combination which would regulate the pressure used in case of the apparatus available.

In brief, he found that a nozzle of form specified in *Fig. 2* (called a ¼-inch nozzle) in combination with a 2-inch flat disc would regulate the pressure in a ½-inch pipe to the following extent:

The pressure on the down-stream section of the pipe was preserved constant at 2½ pounds per square inch by the action of the disc while the pressure of the upstream section varied between 10 to 40 pounds per square inch by gage (as shown on *Fig. 4.*)

APPARATUS.

Fig. 1 shows the construction of the apparatus with nozzle, disc, chamber and spider for supporting the disc. The fitting of the apparatus for experimental work is shown in *Fig. 3.* The two gages for measuring the pressures were placed as close as possible to the chamber containing the disc. The fittings were made with great care. The valves shown were for controlling the pressures used in experimentation.

METHOD OF EXPERIMENT.

The apparatus was attached to the standpipe of the hydraulic laboratory, the pressure in which was controlled by a steam pump. Starting with a given standpipe pressure, say 40 pounds by gage, the water was allowed to flow through the apparatus, being throttled by the lower valve to indicate a down-stream pressure of, say, 2½ pounds per square inch on the lower gage. This down-stream pressure

was allowed to remain fixed during the test, the lower valve not being disturbed. The upstream pressure was varied by use of the upper valve, throttling the upstream section. In this way upstream pressures of from 40 pounds per square inch down, by steps of 5 pounds per square inch, to the lower

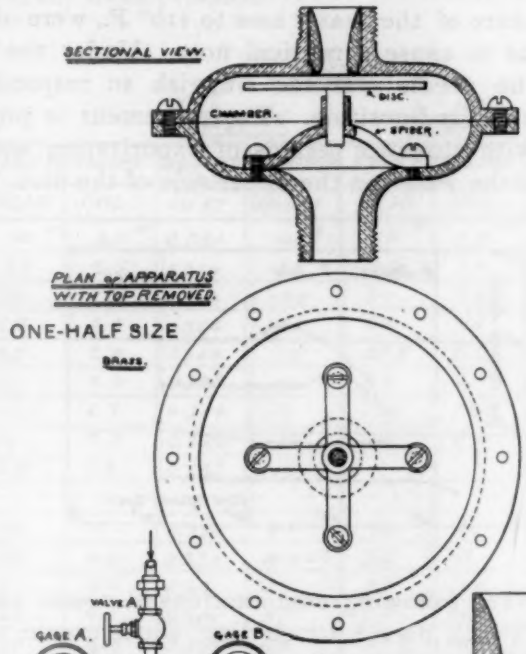


FIG. 1.

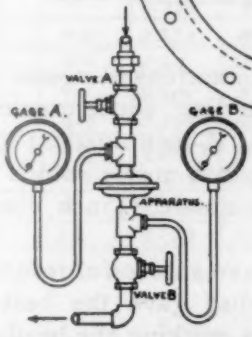


FIG. 3.

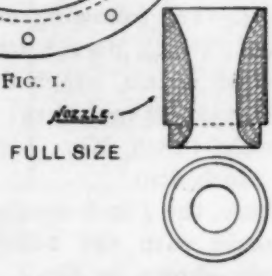


FIG. 2.

limit were effected. The apparatus discharged into a weighing tank and the discharge was weighed. The temperature of the water was taken every minute, because this temperature varied greatly throughout the tests, due to the fact that the standpipe tank was connected to the condenser of a

Corliss engine. With respect to the effect of temperature on the results, it may be said that when the temperature of the discharge rose above the 100° F. the tail pressure-gage showed a very unsteady pressure, the needle vibrating with a range of as much as one-half pound. The disc was no doubt at this time subject to vibrations, which, when the temperature of the water rose to 110° F., were of such frequency as to cause a musical note. Under the latter condition the needle was too sluggish to respond and remained at a fixed position. The movement is probably connected with alternate periods of vaporization and condensation of the water on the upper side of the disc.

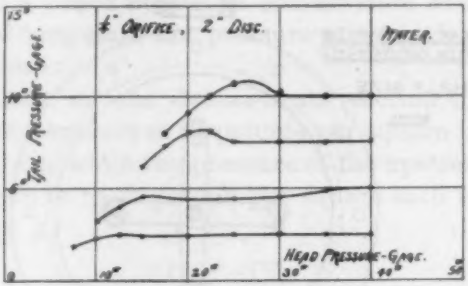


FIG. 4.

Results.—The following combinations of nozzle and disc were used: $\frac{1}{8}$-inch nozzle, 1-inch disc; $\frac{1}{8}$-inch nozzle, $1\frac{1}{2}$-inch disc; $\frac{1}{8}$-inch nozzle, 2-inch disc; $\frac{3}{16}$-inch nozzle, 1-inch disc; $\frac{3}{16}$-inch nozzle, $1\frac{1}{2}$-inch disc; $\frac{3}{16}$-inch nozzle, 2-inch disc; $\frac{1}{4}$-inch nozzle, 1-inch disc; $\frac{1}{4}$-inch nozzle, $1\frac{1}{2}$-inch disc; $\frac{1}{4}$-inch nozzle, 2-inch disc.

Of these, the $\frac{1}{4}$-inch nozzle gave successful results; the $\frac{1}{4}$-inch nozzle with the 2-inch disc gave the best results. These are shown in *Fig. 4*. In working the head pressure down toward the tail pressure the former would approach a critical point at which the difference of pressure became so slight that the regulating effect ceased and both head and tail gages suddenly moved to the same reading. The disc at this period no doubt dropped away from the jet. That is, a certain difference of pressures is needed to enable the appa

ratus to work. This difference of pressure became greater as the tail pressure was increased, as is shown in *Fig. 4*.

In experiments with the other orifices mentioned, the lines shown in *Fig. 4* became straight lines inclined to the horizontal. The hump in *Fig. 4* was characterized by an unsteady head pressure.

WATER.

¼" ORIFICE 2" DISC.

GAGE PRESSURE.		DISCHARGE PER MIN. CU. FT.	TEMPERATURE OF WATER.	GAGE PRESSURE		DISCHARGE PER MIN. CU. FT.	TEMPERATURE OF WATER.
HEAD.	TAIL.			HEAD	TAIL.		
40 #	2.5 #	0.301	105° F	40 #	7.5 #	0.334	88 ° F
35	2.5	0.304	105	35	7.4	0.337	92
30	2.5	0.304	108	30	7.5	0.342	93
25	2.5	0.304	109	25	7.5	0.342	93
20	2.4	0.300	112	22.5	8.2	0.342	95
15	2.4	0.300	112	20	8.	0.350	96
12.5	2.5	0.304	111	17.5	7.25	0.323	95
10	2.3	0.282	106	15	6.2	0.314	94
7.5	1.9	0.267	112				
- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
40	5	0.330	95	40	10	0.377	82
35	4.8	0.322	100	35	10	0.385	81
30	4.5	0.315	99	30	10.2	0.388	80
25	4.4	0.306	97	25	10.1	0.388	78
20	4.4	0.306	100	22.5	10	0.385	78
17.5	4.5	0.315	105	20	9	0.361	78
15	4.5	0.315	104	17.5	8	0.336	78
12.5	4.	0.302	105				
10	3.2	0.270	108				

FIG. 5.

One disc was beveled so as to give a constant area of passage-way to the expanding ring of water; that is, it was dished, with the deepest part next to the nozzle. This disc preserved a constant difference of pressure between the head and tail pressures.

Some experiments were carried on with air as the fluid passing through the pipes. With the nozzle and discs used

there appeared to be no governing effects in case of these air pressures.

In general, it may be said that the shape of the nozzle has most to do with the action observed. A number of nozzles of different form were used; those most nearly like that shown on *Fig. 2* gave the best governing effect.

The size of the disc affects the results obtained with any given nozzle. The 2-inch disc gave better results than the 1-inch or the 1½-inch disc.

The action desired could be obtained with water at a temperature of 75° F. as well as at the higher temperatures.

A very pretty cylindrical sheet of water could be obtained by removing the lower part of the casing. The disc acted like the well-known ball nozzle. Under these conditions, with a head pressure of 40 pounds and a nozzle velocity (as figured from the discharge) of 14·6 feet per second, it was found necessary to exert a force of 9 pounds to pull the disc from the jet.

IMPROVEMENT IN THE METALLURGY OF ALUMINUM.

The hydrate of aluminum, like most colloidal precipitates, retains with great tenacity considerable quantities of the precipitant and also of the radical with which it was before combined, a most unfortunate circumstance from a mettallurgical point of view, for as the hydrate is separated by the reaction of carbonic acid gas on sodium aluminate, very appreciable percentages of sodium carbonate, amounting in some cases to 7 per cent., are held by the precipitate, and passing into the electrolytic cell are decomposed, resulting in the contamination of the aluminum with more than mere traces of the alkali metal. Mr. H. W. Jordan, of Syracuse, observes that the amount of salt so retained is governed largely by the temperature of the reacting gas, and that by superheating the carbonic acid to a temperature above the normal boiling point of the aluminate solution, and preferably to 400° F., the quantity of carbonate held by the hydrate can be reduced below one-half of one per cent.—*Electrical World.*

MOVING A BRIDGE.

An engineering feat, which for magnitude and quick execution has seldom been equaled, was accomplished on May 25 at New Brunswick, N. J., by the Pennsylvania Railroad Company. The bridge crossing the Raritan river and the draw connecting, which span the Delaware and Raritan Canal, were moved 14 feet 6 inches in one minute and forty-three seconds. The length of the bridge and draw is 906 feet. The bridge has five spans, each 150 feet long, and the draw span is the same length. There was no interference with the regular railroad schedule.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 19, 1902.

President JOHN BIRKINBINE in the chair.

The Metric System of Weights and Measures.

(*Continued from page 72.*)

To the Franklin Institute:

In 1876 the Boston Society of Civil Engineers, in conjunction with many of the most active scientific societies in the country, issued a circular to all scientific and technical institutions of the United States, asking them to join in a petition to Congress to fix a date after which the metric weights and measures should be the only legal standards. The acceptance of this invitation was very general; but to the surprise and regret of many of its stanchest friends and the educated public generally, the Franklin Institute, through a majority of one of the committee of three it appointed to consider the subject, reported against the adoption of the metric system. The report of the minority of this committee, the late Mr. Robert Briggs, which was strongly in favor of the change, was published with the majority report in the *Journal of the Franklin Institute*, June, 1876 (Vol. ci, No. 606, p. 370 +). Mr. Briggs afterwards participated in the joint discussion held by the American Institute of Mining Engineers and the American Society of Civil Engineers in New York, February, 1877. The objections of the two gentlemen, Dr. Coleman Sellers and Mr. W. P. Tatham, constituting the majority of the Franklin Institute's committee, were roughly as follows:

(1) Some reform of weights and measures in France was necessary when the metric system was adopted, but none was necessary in the United States, where the weights and measures are uniform by law (?).

(2) The terrible French Revolution was invoked to disparage any proposition emanating from French soil.

(3) The character and habits of the French people were similarly used.

(4) Most of the points of John Quincy Adams' report were reproduced and his question of the power of the Government to "fix" a standard.

(5) The meter was said to be a less convenient measure than the 2-foot rule.

(6) By changing our unit it was urged we would destroy our conformity with Great Britain.

(7) The change would entail too great expense.

TABLE I.—COMPARATIVE CHART OF METRIC LINEAL MEASURE.

	Millimeter.	Centimeter.	Decimeter.	Meter.	Dekameter.	Hektometer.	Kilometer.	Myriameter.
Millimeter	1	10	100	1000	10000	100000	1000000	10000000
Centimeter	0·1	1	10	100	1000	10000	100000	1000000
Decimeter	0·01	0·1	1	10	100	1000	10000	100000
Meter	0·001	0·01	0·1	1	10	100	1000	10000
Dekameter	0·0001	0·001	0·01	0·1	1	10	100	1000
Hektometer	0·00001	0·0001	0·001	0·01	0·1	1	10	100
Kilometer	0·000001	0·00001	0·0001	0·001	0·01	0·1	1	10
Myriameter	0·0000001	0·000001	0·00001	0·0001	0·001	0·01	0·1	1

TABLE II.—COMPARATIVE CHART OF ENGLISH LONG MEASURE.

	Barley-corns.	Inches.	Hands.	Links.	Feet.	Yards.	Fathoms.	Rods.	Chains.	Furlongs.	Miles (st.)	Miles (ge.).	Leagues.
Barleycorns	1	3	12	23·76	36	108	216	594	2376	23760	190080	220176	570240
Inches	1·33	1	4	7·92	12	36	72	198	792	7920	63360	73392	190080
Hands	0·083	0·25	1	1·98	3	9	18	49·5	198	1980	15840	18348	47520
Links	0·042	0·126	0·555	1	1·515	4·545	9·09	25	100	1000	8000	9266·66	24000
Feet	0·0278	0·083	0·33	0·66	1	3	6	16·5	66	660	5280	6116	15840
Yards	0·0092	0·0278	0·1111	0·22	0·33	1	2	5·5	22	220	1760	2038·66	5280
Fathoms	0·0046	0·0139	0·0555	0·11	0·165	0·5	1	2·75	11	110	880	1019·33	2640
Rods	0·00167	0·00505	0·0202	0·04	0·0606	0·1818	0·3636	1	4	40	320	370·66	960
Chains	0·000421	0·001262	0·00505	0·01	0·01515	0·04545	0·0909	0·25	1	10	80	92·66	240
Furlongs	0·0000421	0·0001262	0·000505	0·001	0·001515	0·004545	0·00909	0·025	0·1	1	8	9·266	24
Miles (st.)	0·00000526	0·0000158	0·0000631	0·00012	0·000189	0·0005681	0·001136	0·003125	0·0125	0·125	1	1·1582	3
Miles (geo.)	0·00000454	0·0000136	0·0000545	0·000108	0·000163	0·000494	0·000981	0·002697	0·010792	0·10792	0·86·4	1	2·59
Leagues	0·00000175	0·0000526	0·00002103	0·00004	0·000066	0·00018936	0·0003786	0·0010416	0·004166	0·041666	0·3333	0·38666	1

Meters.		Meters.		
		0·001	Millimeters.	1
		0·002		2
		0·003		3
		0·004		4
		0·005		5
		0·006		6
		0·007		7
		0·008		8
0·00846	Barleycorn			
		0·009		9
		0·01	Centimeters	1
		0·02		2
0·0254	Inch (=3 barleycorns)			
		0·03		3
0·0305	Foot tenth (=1·2 inches)			
		0·04		4
0·05715	Nail (=2·25 inches)	0·05		5
		0·06		6
		0·07		7
		0·08		8
		0·09		9
0·1016	Hand (=4 inches)	0·1	Decimeters.	1
0·1558	(Cube root of wine gal. or 231 cub. in.=6·1538 in.)			
0·1665	(Cube root of beer gal. or 282 cub. in.=6·5576 in.)			
0·2012	Link (=7·92 inches)	0·2		2
0·2286	Quarter (=9 inches)			
0·3048	Foot (=12 inches)	0·3		3
0·3278	Cube root of bushel (=1·907 inches)			
		0·4		4
		0·5		5
0·5715	Ell Hamburg (=2¼ quarters)			
		0·6		6
		0·7		7
		0·8		8
		0·9		9
0·9144	Yard (=3 feet)			
0·9837	Cubic root of wine tun=38·78 inches			
1·143	Ell English (=5 quarters)	1	Meters.	1
1·3716	Ell French (=6 quarters)			
1·5631	Cube root of cord (=5·0397 feet)	2		2
1·829	Fathom (=6 feet)	3		3
		4		4
		5		5
5·0292	Rod, pole or perch (=5·5 yards)			
		6		6
		7		7
		8		8
		9		9
		10	Dekameters.	1
		20		2
20·1164	Chain (=4 rods=22 yards)			
		30		3
		40		4
		50		5
		60		6
63·6148	Square root of an acre (=69·57 yards)			
		70		7
		80		8
		90		9
		100	Hektometers	1
		200		2
201·168	Furlong (=10 chains=40 rods)			
		300		3
		400		4
		500		5
		600		6
		700		7
		800		8
		900		9
1609·31	Statute mile (=8 furlongs)	1000	Kilometers	1
1863·62	Geographical mile (=1·158 statute miles)			
		2000		2
		3000		3
		4000		4
4828·02	League (=3 statute miles)			
		5000		5
		6000		6
		7000		7
		8000		8
		9000		9
		10000	Myriameters.	1

(8) The measurement of every plot of ground in the United States had been made in acres, feet and inches.

(9) But *all* of the objections against the metric system did not apply to the decimal division of the present units (!).

The present writer answered these points specifically in a paper read before the Philadelphia Social Science Association on December 28, 1877, and Mr. John W. Nystrom, then a leading and active member of the Institute, recognizing the impossibility of introducing his tonal (or sixteen) system, and at the same time appreciating the immense advantage, over any other yet devised, of the metric system, strongly supported it and condemned the majority report of the Franklin Institute's committee.

At this time the American Metric Bureau, through its Secretary, Mr. Melvil Due (Melville Dewey), was active in having the metric system introduced as a compulsory study into the primary schools, in endeavoring to arouse public opinion to the necessity of securing uniformity with the rest of the world, and in urging its adoption by the United States.

As long ago as 1860 the values of exports and imports of countries using the metric system were respectively seventeen and fifteen times those of countries not using it. Since then Germany and many smaller countries have adopted it and the disparity between the two classes is much greater. The only three large countries which have not completely substituted it, viz.: Russia, England and the United States, have all legalized it in part, and the legislative bodies of the last two have several times been within a few votes of adopting it exclusively.

Some of its advantages are: (1) in the immense saving of time and avoidance of the danger of errors in computations by at once exhibiting the relations of linear and cubic space, weight and specific gravity, and preserving them throughout the usual mathematical operations.

(2) The production of an infinite scale in which the units of measure are equally distributed; from the infinitesimal, used in calculating the diameters of molecules, to those employed in stating the distances apart of celestial bodies. The Anglican system consists of groups of incommensurable units unevenly scattered over a few areas of the entire gamut of measure.

(3) Even if the unit base, the concrete meter stick, should prove to be more or less than the exact ten-millionth of a quadrant of the earth's meridian anywhere, its actual value is fixed, as all other lineal measures have been, by carefully prepared standards, and by the carefully observed phenomena of their relations to the second's pendulum at many points of the earth's surface. When uniformity among civilized nations is once established, should it ever be thought desirable to secure closer approximation to any natural terrestrial unit, this can easily be done by mutual agreement and by all nations together.

A detailed consideration of the whole subject will be found in my paper before cited, and in a paper by me read April 5, 1878, before the American Philosophical Society, on the interconversion of the metric and English units.

I have added the three tables from the first of the papers above referred to, for the purpose of illustrating the greater simplicity and the more perfect adaptability to the measurement of very large or very small quantities, of the metric system.

A comparison of Tables I and II will show the enormous difference between the two scales in the facility which they respectively offer for the conversion of one unit into another.

Table III shows but a single English measure between 8 and 9 of the first group of ten in the metric scale. Three English units appear between the 2 and 7 of the second (centimeter-decimeter) group of ten. Seven units are seen between the 1 and 5 of the decimeter-meter group, and two beyond the 9 of this group. Four units lie between the 1 and 2, and one between the 5 and 6 of the meter-dekameter group of ten. Two units occur within the dekameter-hektometer ten ; one within the hektometer-kilometer ten ; and three between the kilometer-myriameter ten.

There are no other named English measures, but the metric units have just begun. By the same simple decimal division and multiplication, as many more groups of ten of the infinitesimal or of the greatest units may be at once provided, each so related to the ordinary units by similar and uniform multiples that the determination of the value of one unit in terms of any other involves no transaction more difficult than the transfer of a decimal point.

If we desire to convert yards into geographical miles, or barleycorns into links, much more time would be necessary and much greater liability to error incurred.

But the great merit of the system is seen when one wishes to calculate rapidly the weight of, say, commercial oil of vitriol in a given cubic content.

The weight in metric tons (a unit closely approximating the English short ton) is the product of the length, breadth and height in meters and the specific gravity (1·84 in the case supposed) of the fluid, water at specified temperature and barometer being 1.

In conclusion, I would refer to the very able and exhaustive report on the adoption of the metric system and on metric coinage presented by the Committee on Coinage, Weights and Measures of the House of Representatives of the 46th Congress, 1st Session, Report No. 14, Alexander H. Stephens, chairman.

Respectfully,

ROOM 1042 DREXEL BUILDING, PERSIFOR FRAZER.
PHILADELPHIA, February 7, 1902.

THE TABOR MANUFACTURING COMPANY.

PHILADELPHIA, February 18, 1902.

To the Secretary:

In response to your request for an expression of my views on the adoption of the metric system in the United States, and in view of the possibility of being unable to attend the meeting of the Franklin Institute to consider the question to-morrow night, I may say that I was led to endorse the action of the special committee of which I am a member, from the preponderance of evidence in its favor, and not because I consider the metric system as ideal in every respect.

I have never regarded it with favor from the standpoint of practical utility in the workshop, because the numeration does not permit of continuous subdivision by 2.

This inherent defect, for which the system is not primarily responsible, can, of course, never be eradicated except by a revolution which would for a time involve the whole industrial world in a chaos of doubt and confusion. The benefits to be derived from a change in our system of arithmetical notation are obvious, but the difficulty of unlearning the multiplication tables to which we are accustomed, and learning new ones which will more perfectly harmonize the practical and theorectical conditions to be met, seems to me insurmountable.

There are too many or not enough unit figures in the Arabic system of notation, and the simplest conceivable change would be to obliterate the numerals 8 and 9. If this were done we would then have a decimal system capable of continuous subdivision by 2, and a metric system adapted to this notation would be ideal in every respect. Subdivision by 2 is the simplest and most natural method of scaling down, and that it will continue to assert itself whether the metric system prevails or not is evidenced in many ways. We have already a decimal currency, but in spite of this, stocks continue to be quoted in fractions of halves, quarters, eighths and sixteenths, and brokers take commissions of $\frac{1}{8}$ and $\frac{1}{16}$ of 1 per cent. The kilogram is divided into halves and quarters, for the convenience of tradesmen, and the tendency to divide all metric units in the same way, thus leading to longer and longer decimals in the expression of values, can never be checked. And again, for lineal dimensions there is no scale comparable in clearness with that formed by the natural method of continuous subdivision by 2, and in the use of such a scale for drawing, no decimal scale can compare with it in adaptability.

That the metric system does not lend itself to this natural method of subdivision seems to me deplorable but irremediable in our present advanced stage of civilization.

We have started wrong and cannot change however much we may desire to do so; the accumulations of knowledge are too vast to be modi-

fied, and as a matter of fact there is no alternative but to accept the inconvenient Arabic system of notation as forever fastened upon us.

Then, having done this, it is perfectly clear that there is but one system of weights and measures in the world to-day, and the best that can be devised on the notation to which the whole world is committed.

The practical convenience of the workshop must, I believe, give way to the overwhelming theoretical advantages of the metric system. These advantages cannot be successfully disputed, and I have therefore been compelled reluctantly to admit the adoption of the metric system as a wise step for this country to take. Any system is better than none at all, and no system founded on the natural subdivision by 2 would with our present notation be acceptable to the great army of thinkers who plan the work of the world.

Therefore, let us have the best attainable, though it may not be the best conceivable. Yours truly,

WILFRED LEWIS.

BROWN & SHARPE MANUFACTURING COMPANY.

PROVIDENCE, R. I., February 18, 1902.

To the Secretary:

We have yours of February 1st, giving notice of the meeting, the discussion before the Institute, and its committee's report on the "feasibility and advisability of adopting the metric system of weights and measures in the United States."

We regret that we shall not be able to attend this meeting or to send any representative.

We would understand that the purport of such report as has been made is the support of certain legislation by the National Government, which is favorable to a general adoption of the metric system of weights and measures in this country. We would say that in general we are opposed to such legislation for several reasons.

In the absence of convincing argument to the contrary, we would feel, first, that the metric system in itself is not a better system than the English for the purposes of engineering trade; and secondly, even granting its merit, we question whether any such enactments of the National Government would accomplish the desired ends. We believe the American people are too much wedded to the English system to give it up because of any national legislation. We well know that the support of the Franklin Institute will carry more or less weight for or against the proposed measure, and trust that, if it is deemed advisable to adopt any measures of such character, it will be along the most conservative lines. We are

Respectfully yours,

BROWN & SHARPE MFG. CO.,

HENRY D. SHARPE.

GENERAL ELECTRIC COMPANY.

LYNN, MASS., February 13, 1902.

To the Secretary:

I am glad to note that a special committee of the Franklin Institute has taken up the question of the adoption of the metric system for our standards, and has reported upon the matter favorably.

In my opinion we need the system, and I hope it will become international. We need it because it is a rational system connecting measures of length with those of area, volume, etc. It appears to me that our people have been long enough under the incubus of "long" and "short" tons, "long" and "short" hundredweights, "dry" quarts, "liquid" quarts and the like; units without any rational relation, or often with curious fractional relationship to one another.

I doubt whether there are many persons who could state the various measures and their values as learned in childhood. If such measures as our measures of length in feet and inches were the only things concerned, I should not advocate a change, but the question is far broader than that of a set of linear units, and the metric system is the only existing rational system which can be substituted for the irrational measures we now have.

I realize that in changing to the metric system, many of our industries will be subjected to some confusion and perhaps considerable expense. I do not think the change can be forced or accomplished by any sudden, revolutionary, process. It seems to me that ample time should be allowed for the transition; in fact, a period of not less than two or three years.

While I have never regarded the measures of length of the metric system as the most ideal for practical purposes, still no better system exists, and it is decidedly too late to devise any new systems. I hope the National Government will soon enact such laws as will insure the ultimate adoption of the metric system as our standard.

I may add, in conclusion, that I have been in consultation with most of the heads of departments and engineers of the General Electric Company, and find that on the whole they are favorable to the adoption of the metric system, especially on new work, with the idea that it would eventually entirely displace existing measures. When it is borne in mind that in the business of machine manufacturing, the cost of gages and other tools made in standard dimensions is a large item, and that the change means the production of other gages, etc., in the new system, it is indeed surprising that so little opposition to the proposed change has arisen.

It is beginning to be generally believed, I think, that the ultimate advantage will be greater than the temporary disadvantage, and that the longer we go on without making the change, the more difficult and costly will the carrying out of any such substitution become.

Yours very truly, ELIHU THOMSON.

BEMENT, MILES & CO.

PHILADELPHIA, PA., March 3, 1902.

To the Secretary:

In the matter of adopting the metric system of weights and measures in the United States, our views upon the subject were not given upon first request, as we thought the matter required more consideration than we found time to give it, before placing ourselves upon record either for or against the change.

As the request has again been made for our opinion, can only say we give it from our point of view and in connection with our particular line of business. Were we to pass upon the simple question of the advisability of having a uniform standard throughout the civilized world, and without regard to the inconvenience and expense incidental to the change, we would decide in the affirmative. We would also be an advocate of adopting the metric system on account of it being more universally used than any one system, rather than to attempt to force the British standards, even though considered as convenient.

From what we have said thus far, you will see we are, in a general way, in favor of a common system of weights and measures, and the system should be the metric.

On the other hand, considering the matter in connection with our own manufacture, or, to make it more definite, our manufacturing establishment, we do not believe the time is opportune for adopting this system, as it would lead to considerable expense if it were carried out to a degree that would make it an international benefit. We could readily, and without much expense, express dimensions of tools, fixtures, etc., in metric symbols, but would this be any real advantage unless the pieces so expressed were exact duplicates of similar pieces in use by countries whose standard is the metric system?

Were the decimal system to be used, we would find it necessary, as a matter of economy and to be able to duplicate parts for repairs, to adhere to sizes now in use and merely express them differently. This sort of adopting the system would not, to our way of thinking, lead to the desired point.

To reach the object we are after, we would have to equip our places with new tools and fixtures that would be uniform in size as well as expression, among all nations using the metric system. This would mean, for many years, carrying a larger stock of tools, and of course increasing the investment without a corresponding increase in the output.

Considering the many exports made to countries where the metric system is in use, we have found it necessary in very few instances to conform to metric sizes, and in fact, only in such machines as lathes where the lead screw had to be a decimal pitch. These modifications

were readily made, and the balance of the machines made to our ordinary standard.

As we think the change would increase the expense and create more or less confusion, without materially increasing the sales, it is a natural conclusion that we would not favor the change until convinced the view taken by us is wrong.

Yours very truly,

BEMENT, MILES & CO.,

W. J. HAGMAN, *General Manager.*

TREASURY DEPARTMENT, OFFICE OF THE COAST AND GEODETIC SURVEY.

WASHINGTON, D. C., February 13, 1902.

To the Secretary:

Your courteous invitation to take personal part in the discussion of the report of your special committee on feasibility and advisability of the adoption of the metric system, is before me. I regret that circumstances prevent my being present, but I gladly avail myself of the invitation to submit some comments.

I doubt whether any discussion is needed of the broad subject whether a common system of weights and measures is desirable. That, I think, will be admitted by every one. Forty years ago, the question whether the British system or the metric would ultimately prevail may have been open to discussion. Now the progress of the latter, its adoption by Germany and by Norway and Sweden, its extension in Mexico and South America, its adoption by all scientific men in the researches from which results nearly all human progress, have settled that question.

Its progress among scientific men cannot be ascribed alone to the advantage of having a common system. It must be due largely to the fact that it is a labor-saving device of vast importance. Viewed from that standpoint alone, the temporary inconvenience and cost which a change might involve, would, in my judgment, be insignificant as compared with the inconvenience and cost which the continued use of the customary weights and measures entail on every generation of our rapidly growing population on account of the loss of time and waste of mental energy involved in the use of our heterogeneous weights and measures.

It is not a new thing to change weights and measures. Aside from the recent example set by other nations in the radical adoption of the metric system, the English weights and measures have continually undergone change, though the names may have been retained.

In our country the agrarian measure of the arpent has disappeared from the Louisiana Purchase. The vara was in use in the territories acquired from Mexico and California. The lack of inter-relation between our units of weight, length and volume clearly indicates that they

are the remnants of different systems, for no human ingenuity would ever have devised, at any one time, anything so wonderfully complex as our existing weights and measures.

It certainly is the province and duty of the Government to take part in the reform of its weights and measures. The Constitution has provided that Congress shall fix the standard of weight and measure, and, in the nature of things, individual effort can only be directed towards urging Congress to act, because the individual cannot adopt any particular system, though it may be permissive, for he is dependent on its adoption by others before it can be used profitably by himself except, of course, in intellectual pursuits.

The question may be raised, as it always has been, whether the time is opportune for the change. To this the answer seems to be that the difficulties are more apt to increase than to decrease with the lapse of time. The rivalry between commercial nations was never greater than now, and a common system of weights and measures is certainly a great aid in promoting an interchange of commodities.

There can be no doubt that Great Britain would promptly follow the lead of the United States. The fact is, these two nations seem to wait upon each other for the first step. The agitation for the adoption of the metric system is as great in England as it is in this country. It is true we are in fair accord with Great Britain, but we are out of tune with the southern half of our continent.

It cannot be believed that Mexico and South America will ever recede from the use of the metric system any more than that we will recede from our system of decimal coinage. Its extension and common use there seems certain, and it is also certain that those countries are sure to become of much greater importance in the commercial world than they are at present.

For all these reasons I am heartily in accord with the tenor of your resolutions. Yours very truly,

O. H. TITTMANN,
Superintendent.

SMITHSONIAN INSTITUTION.

WASHINGTON, U.S.A., February 8, 1902.

The Committee of the Franklin Institute on the Adoption of the Metric System in the United States.

GENTLEMEN:—I am fully in accord with the report of the Franklin Institute that the metric system is commendable, not only as a suitable international standard, but for facility of computation and in other ways; and I approve of any modification which will promote the general introduction of the metric system with a minimum of loss.

I do not forget that the considerable capital invested in present standards and in machinery using them will be rendered nearly valueless by such a change, and, having this in view, I still think that the change would be worth more than any probable cost.

Very respectfully yours,

S. P. LANGLEY.

WILLIAM SELLERS & CO., INCORPORATED.

PHILADELPHIA, February 19, 1902.

To the Secretary.

SIR :—I am in receipt of your favor of the 1st inst., requesting me to express my views on the "feasibility and advisability of adopting the metric system of weights and measures in the United States." I have also received the report of the special committee of the Franklin Institute appointed to consider this subject, and the pamphlet of the American Metrological Society, advancing arguments in favor of the adoption of the metric system.

By "adoption" I understand is meant enforced adoption by legislative enactment, and presume that this question, which has been forced into prominence at intervals during the past century, is again re-opened because Congress is considering a bill designed with this intent.

I have not seen the text of this measure, but understand it requires all Departments of the general Government to use the French metric system except for land measurement, the expectation being, doubtless, that the resulting inconvenience to those dealing with the Government will tend to bring the French system into more general use.

I do not think any great hardship would be involved if the Government should require the Army and Navy stores—the coal, salt pork, hard tack, molasses, etc.—to be measured in kilograms and liters instead of pounds and gallons, although I confess I do not see any particular advantage in such a course; but before forcing this change on all Departments, I think the cost, direct and indirect, should be carefully considered.

The Government is a large buyer of many kinds of manufactured products, and, in order to buy at reasonable rates, must buy what the market supplies; that is, must use what other purchasers require. For example, we have certain standard sizes of pipes and fittings threaded with so many turns per inch; these are well recognized, and we are able to buy pipe of one man and valves or other fittings of another man with reasonable certainty that they will fit one another, and many expensive tools and gages are required to produce this degree of uniformity. Is it intended to forbid the Government to buy such pipe and fittings and require it to have made special pipes in millimeter sizes with

threads in millimeter pitches? It is hardly conceivable that any one understanding the subject should recommend such a course.

The case is the same with our convenient series of bar sizes, our sheet and wire gages, our bolts, nuts and screws and many other commercial standards in all branches of business. It is true that these conventional sizes are perhaps more or less crude and imperfect; but they are well understood and serve their purpose, and experience has shown how difficult it is to change them when better series have been suggested. It is said that we need not change any actual sizes, but simply call them by new names. For years we have been trying to increase the accuracy of the sizes of things—to have the inch bar or the inch bolt measure 1″ in diameter and not more or less; but if we must call our 1-inch bar a 25 mm. bar, which it is not, it seems to me we are retrograding instead of progressing.

The great convenience that was expected from the decimal division of measures has proved largely a delusion, and it is admittedly impracticable to overcome entirely the natural tendency to binary division. It is admittedly impracticable to change our land measures and I believe equally impracticable to abandon our pipe and screw-threads, our wire gages and many other standards, as well as the vast amount of engineering data now stated in our present units. I cannot see that anything is possible but a partial introduction of the French system amounting certainly at first to a mere change of names.

If any one now desires to adopt or use all or any part of the French system he is at perfect liberty to do so. The Government has already legalized the French units and has moreover provided standards of weight and measurement to which all may refer. In my judgment the general Government has thus done its whole duty in the premises. I am not an advocate of that kind of despotic paternalism which interferes too much with the private affairs of the citizen. The French system has been gladly adopted in the laboratories of scientific men, and its further general adoption will proceed as rapidly and to the extent that the system proves itself better or more convenient in any way than the simplified English system which we now employ. It appears, however, that the advocates of the French system are not satisfied with the natural process of extension and therefore seek to bring about the general use of the system by legal coercion in the absence of any demand for such legislation from the people at large.

I believe that without a popular demand for such a change, any attempt to force the French system into use by legal coercion will prove largely abortive. Yours truly,

C. SELLERS, JR.

PHILADELPHIA, February 10, 1902.

To the Secretary:

In reply to your circular letter of 1st inst. in regard to the metric system, I would say that I am most heartily in favor of the adoption of the report of the committee, with perhaps one slight exception. In weights and measures of capacity I have for many years worked with both systems, and by practical experience have found the metric system as far superior to our present system (or rather want of system) as our decimal currency is in advance of the English £ s. d.

When, a generation or two hence, the history of the present time is written, one of the things that will seem most incredible will be that a nation as far advanced in civilization as the United States is supposed to be, should be weighing its copper by one standard, its silver by another, its diamonds by a third and its medicines by a fourth, all of them interchangeable only by means of fractions, and measuring its wines by one system, its grain by another and its gas by a third.

The use of the metric system for weights and measures of capacity will cause the less inconvenience because of the fact that our present weights and measures are of comparatively large units, fine determinations in most cases being even now made in the metric system. Its use for lineal measurement will cause more difficulty, because of our present machines and tools having been made to inches and fractions, but I fully believe the temporary inconvenience will be much more than compensated by the convenience of the metric system.

However, it would seem to me to be not impracticable to inaugurate the system for weights and measures of capacity in advance of lineal measures, if it be thought by a majority that the change in lineal measurement is not advisable. Should it be adopted so far, its advantages will be so manifest that the other must follow in due course.

Truly yours,

THEO. D. RAND.

OFFICE OF THE CHIEF OF ENGINEERS, UNITED STATES ARMY.

WASHINGTON, February 10, 1902.

To the Secretary:

* * * I do not hesitate to say that I am heartily in favor of any movement which will bring about the adoption in this country of the metric system, with the least confusion and expense.

Very respectfully,

G. S. GILLESPIE,

Brig. Gen., Chief of Engineers, U. S. Army.

[*To be concluded.*]

Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.*]

Steel Rails: Relations between Structure and Durability.

By Robert Job,
Chem'st to the Philadelphia & Reading Railway Company.

(*Concluded from p. 31*)

DISCUSSION.

Mr. James E. York:—I have listened to Mr. Job's paper and noted his illustrations with much interest. The diagrams he has presented are very instructive as showing what a remarkable effect the physical treatment has on the wearing qualities of a steel rail. The present method of manufacturing steel rails, with their enormous output to-day, has evidently resulted in deteriorating the durability of the rail as compared with the rails made in the sixties and seventies. This might in a measure be explained by the fact that the rails then were of lighter section than now, and consequently received greater physical reduction, and also permitted of finishing at a lower temperature than at the present time; but this does not explain why the so-called John Brown rails, of which Mr. Job gave us illustrations, have shown such marked superiority over those of recent date, as regards actual service in the track. To explain this superiority we have certainly to look to the physical treatment of the rails. It may be of interest if I read what Mr. Robert W. Hunt writes in *Cassier's Magazine* on the chemical composition of the John Brown rails:

> "* * * The carbon varied from 0·24 per cent. to 0·70 per cent.; silicon from 0·032 per cent. to 0·306 per cent.; phosphorus from 0·077 per cent. to 0·156 per cent.; sulphur from 0·050 per cent. to 0·155 per cent., and manganese from 0·312 per cent. to 1·046 per cent."

The great divergence in chemical composition of the rails made at that period compared with modern practice

makes it interesting to consider how these rails were then manufactured. In my own experience I remember that the rails between 1865 and 1870 were made by first casting a 14-inch ingot, of sufficient length and weight for three-rail lengths. These ingots were allowed to cool down and were then examined thoroughly for physical defects. After examination they were put into a heating furnace horizontally, and slowly brought up to the necessary temperature for manipulation, which consisted in bringing the ingot to the hammer and cutting it into three lengths. Two of the pieces were returned to the heating furnace for subsequent hammering, one piece being left for treatment at this initial heat. It was then hammered down to about 7 inches square and put on one side to cool, and again examined for any apparent surface defects. It was then carefully heated and to a lower heat than the primary heat, and rolled down into the finished rail. The reduction in rolling the rails was much lighter than in present practice, and consequently less severe on the structure of the material. This was necessary from the fact that the rolling mills of that period were much lighter, which necessitated lighter reduction. The rolls ran at much slower speed, permitting of the rolling at lower temperature, and the rails were, as Mr. Job has shown, satisfactory as regards wearing qualities. The output then was very small compared with that at present. It did not exceed 100 tons per day, whereas now 1,000 tons per day is not an unusual output. Then, too, these rails were sold at $100 or more per ton; hence this apparently costly method was considered justified at that period and in those circumstances.

A short time ago I read in *The Iron Age* that Mr. Martin, of the Maryland Steel Company, considered that the desirable temperature at which rails should be finished to secure the best results as regards the fining of the grain in the head of the rail, was in the neighborhood of 700° C. to 750° C. I am inclined to think that there are mechanical objections to finishing at this temperature by the present method of rolling, from the fact that the physical structure of the rolls themselves would not stand such hard usage, and would

therefore necessitate frequent change of rolls. There are only two practical ways of physically fining the grain in steel mechanically; one is by hammering at comparatively low temperature and the other is by rolling at low temperature. The effects of cold-rolling have been clearly and practically shown by the experience of Jones & Laughlins in cold-rolled shafting, in which the tenacity, elasticity and resilience of steel is wonderfully increased, and this justifies my views on this matter, which are that it is necessary to finish rails in a specially constructed universal mill which permits of the use of chilled rolls—the only material in which steel, in any large quantity, can be rolled at any practical, desirable temperature. The present method of rolling is specially objectionable for rolling flange sections at a low temperature, from the fact that the difference in the delivery speed of the rolls on the various parts of the rail section makes it necessary that the temperature of the rail shall be such that the slower delivering parts can stretch or slip to accommodate themselves to the other parts of the section. Should this be attempted at a temperature of 700° C., the rail is liable to have permanent internal strains in the bar. This difficulty would be overcome by rolling universally, from the fact that every part of the bar is practically delivered at the same surface speed.

MR. MARTIN then arose and said, in regard to Mr. York's statement, that what he (Martin) had written was that he considered 750° C. a desirable temperature, and not that he had actually finished rails at that temperature. MR. YORK explained: I intended to say, Mr. Martin, that the temperature of 750° C. was what you considered desirable, and not that you had actually finished at that temperature.

MR. SIMON STROCK MARTIN (Maryland Steel Company, Sparrow's Point, Md.).—In Mr. York's reference to my article in *Iron Age*, of December, 1901, he erroneously uses the critical point temperatures of 750° C. steel as being temperatures that we have attained in finishing rails.

As to rolling at temperatures given, I wish to explain that these were obtained by the use of the water calorimeter, and this calorimeter checked with Le Chatelier pyrometer, and

would say we obtained temperatures as given, and get very good tonnages off sand rolls. We nevertheless use some chilled rolls, as he suggested should be done, and I know of other mills that use chilled rolls exclusively with results only slightly better than off sand rolls; and as with chilled rolls for rails, the tendency is for the deep collars to part from the body of the roll, on account of the unequal expansion of collar and body of roll, so much more so than with sand rolls.

MR. P. H. DUDLEY:—Mr. Job presents interesting and important matter for discussion.

His *Fig. 1* shows the characteristic microstructure of a number of modern rails which have worn rapidly under present service. The section shown in *Fig. 1* is evidently from the top rail of the ingot.

The mineral aggregates are large, exceeding $\frac{1}{100}$ of an inch diameter. Those forming the surface of the rail-head, under the weight of the wheel loads, break or shear and flow both in longitudinal and lateral directions. This is a characteristic form of wear under heavy service for all rails, though the rate is not as rapid with tough, fine-grained metal as rails of coarse structure. Near the surface of the head layers of the large mineral aggregates will break down to a depth of $\frac{1}{32}$ and sometimes as much as $\frac{1}{16}$ of an inch in depth, and then large portions of the metal become detached from the sides of the rail.

The structure shown in *Fig. 8*—while the polyhedrons are as large or even larger than that shown in *Fig. 1*—is a different structure and has much greater tenacity, though in the surface of the head the mineral aggregates will break down by shearing under the wheel treads, but not as rapidly as that shown in *Fig. 1*.

One of the important features of Mr. Job's paper is that relating to excess of foreign matter—oxides, slag and enclosed gas, represented by *Fig. 2*. Such matter in excess in the metal renders the ingot or a portion of it unsound, which is not always remedied by cropping the bloom.

The larger ingots having a smaller percentage of columnar structure than the former small ingots, the metal shows

wear quickly in the present heavy rails under the heavy wheel loads. The seams in the head of the rail (*Fig. 12*) are due to the excess of foreign matter. The breaking down of the surface of the head of the rails with great rapidity under the present wheel loads shows most rapidly in the top rail of the ingot, which, as a rule, contains the largest percentage of foreign matter.

Regarding the Differences of Structure in Rails.—The finer structure shown in *Fig. 3* gives a better wearing body than that shown in *Fig. 1* or even *Fig. 8*. The layers of mineral aggregates break down by shearing under the wheel treads, the depth rarely extends below the surface over $\frac{1}{32}$ of an inch, a less depth being more common for the center of the rail-head. The structure shown in *Fig. 6* belongs to rails which were manufactured many years ago from small ingots, and were allowed to cool and then reheated before they were hammered into blooms.

I have never been able to obtain a similar structure to that shown in *Fig. 6* from any of our modern rails, even when rolled down to small sections until the rails were barely red. Some of the specimens from older rails which were hammered have shown nearly a similar structure. The rails from the hammered blooms had from 18 to 20 passes in the different trains before the rail was finished; each reduction was very light and the trains were run at moderate speeds. The capacity of the mills averaged from 60,000 to 70,000 tons per year. Those rails which were imported cost from $120 to $140 per ton in gold, and while they have rendered exceptionally good wear, the small mechanical element of stiffness of the sections compared to their weight only enabled very light axle loads to be carried over them. The number of cross-ties which those rails have required would more than have covered the cost of stiffer rails, and while they could be used in yards where the train movement was very slow, yet out on the main line they have long been too light to be economical.

As to the influence of mill methods upon the size of grain, a number of observations have been recently made on the rails rolled by holding before the finishing pass,

which show more reduction in structure than is indicated by even *Fig. 5*. The comparative wear must be ascertained by actual service.

The steel in the modern rails is now of much greater tensile strength and higher elastic limits than in the rails which were rolled twenty-five and thirty years ago. The higher physical properties can be obtained by proper care without producing brittleness. The form of the sections now is much better adapted to the higher physical properties of the steel than those formerly in use. Their fracture in the track is not nearly so dangerous as in the lighter sections.

Fig. 8 represents structure at center of head of rail which has stood the drop-test, while *Fig. 10* represents structure of a section of the same rail which has been reheated to cherry red and let cool at once in the air. The tensile strength is increased apparently 1,100 pounds per square inch, while the elongation and reduction of area have also increased. Such rails ought to give an increased wear from the fact that the mineral aggregates are so much smaller than the coarser grains shown in *Figs. 1* and *8*. As a girder we depend upon the linear elongation for the modulus of elasticity, while for sustaining the wheel loads upon the surface of the girder we depend more upon the cubic elasticity, or elasticity of volume.

The small grains have a higher cubic elasticity than the coarser grains, the latter failing directly by shearing under the wheel contacts.

That foreign matter in steel lowers the tensile strength, elongation and reduction of area, and in addition tends to brittleness, and that when present in fair excess with high finishing temperature it renders the rails fragile under the drop-test, is true without any question.

The statement that the presence of a relatively large proportion of foreign matter may not produce brittleness, provided the grain of the steel is fine, is true, so far as the longitudinal elasticity is concerned, but for the cubic elasticity, foreign matter permits the head of the rail to crush and deteriorate rapidly under the wheel loads.

In general it is true that to ensure the most desirable rail of a given composition, service tests prove that there must be absence of brittleness and freedom from foreign matter, and presence of fine granular structure. Absence of brittleness is indicated by ability to withstand the drop-test of 2,000 pounds falling 20 feet; that means that the section of rail must be able to take up 40,000 foot-pounds of energy without fracture. This will produce a compression of the metal in the head for a limited length; also an extension of the metal in the base. With a section 5 inches high, a deflection with decided elastic reaction will be produced. If the supports are 3 feet apart, the permanent set for a high-grade rail will be from $1\frac{3}{4}$ to 2 inches. The metal in the head of the rail directly under the drop will have a maximum compression of 5 to 6 per cent., and the metal in the base of the rail will have a maximum extension of 5 to 6 per cent. The metal in the head of the rail will be compressed for a length of 10 to 12 inches, and the base of the rail will be extended for 10 to 12 inches. The width of the head will be widened, while that of the base will be narrowed and thinned down. If the rail is 6 inches in depth, then the same energy, while it will produce almost the same extension or compression of the metal per inch, does not produce as great deflection, the permanent set being about one-half that of the 5-inch section for the same high grade of steel.

On the hypothesis that fine granular structure is ensured by stipulating that the temperature of the ingot or bloom shall be such that with rapid rolling, and without holding before or in the finishing passes or subsequently, and without artificial cooling after the last pass, the distance between hot saws shall not exceed 30 feet $5\frac{1}{2}$ inches for a 30-foot rail (90 pounds), or a proportionate distance for other lengths, it does not appear that Mr. Job has given sufficient consideration to the increased speed and reduction, nor the number of heat units to be dissipated in the large ingots at present in use as compared to the smaller ingots, slower train speeds, lighter reductions, less number of heat units, of the early steel rails. While the cooler rolling of the

metal will improve the quality, it is not all that is required to make good rails for present service. It has now been found by examination, that with the great reduction in the passes and rapid rolling, the metal is often injured and partially separated, so that it develops a weakness afterwards in the finished rail, the ingots having been perfectly sound before rolling.

MR. WM. KENT:—The older members of the Institute of Mining Engineers remember the famous discussions over twenty years ago on the papers of Dr. Chas. B. Dudley, on the wearing power of steel rails. In these papers it was attempted to show what was the relation of the wearing power to the chemical composition and to the physical properties as far as the latter could be determined by the ordinary testing machines. The results of the discussion left the problem an unsolved one, but they showed that the wearing power must depend on something besides the chemical composition—something of which nothing was definitely known at that time. Twenty years ago we knew practically nothing about the microstructure of steel, or about the effect of heat treatment on that structure. Meantime, the manufacture of rails has developed by a tentative method. It has been found necessary to raise the carbon as the weight of the rail has increased, and something has been learned in regard to the amount of work that should be put on an ingot and the temperature at which it should be finished. Mr. Job's paper is the first attempt in over twenty years to put our knowledge of the subject on a scientific basis. It shows not only the relation of wearing power to microstructure, but also how the most desirable microstructure may be obtained. Mr. Job is to be congratulated upon his most important scientific research, and upon his having laid the foundation for much further research in the same direction.

MR. JOB:—Regarding Mr. York's remarks concerning the cause of the durability of the old rails of light section, it has been previously stated that the process then in vogue necessitated thorough working of the steel well down toward the critical temperature. This resulted in the very

fine-grained structure shown in *Fig. 6*, and as a consequence the ductility was far greater than is attained in the practice of to-day with the same composition and the same weight of section, but when the thorough working of the steel is stopped at a higher temperature. In *Figs. 8* and *10* we have seen that the fining of the grain has resulted in a marked increase in ductility and reduction of area, with increased strength, and, as has been shown, we know from service results that such changes with any given composition result in greater durability in actual track service. Thus, the cause of the superiority of the old rails is fully accounted for by the betterments shown in their physical qualities.

In Mr. P. H. Dudley's interesting discussion it is noted that sufficient consideration does not appear to have been given to the increased speed and other conditions of present mill practice, and that, while the cooler rolling of the metal will improve the quality, it is not all that is required to make good rails for present service, since the metal may be injured and partially separated by great reduction in the passes. In the paper I have stated that fine granular form is greatly desired, but that this is only one of several essentials required to effect durability in service. In the cases of separation of the metal mentioned, brittleness would result and would be detected by the drop-test. It is understood that proper mill methods shall be used throughout the process of manufacture, and where this is done we do not find evidences of brittleness.

PETROLEUM DEPOSITS IN MEXICO.

Consul Griffiths at Matamoros reports to the State Department that in view of the scarcity of fuel in Mexico, the exploration and exploitation of oil lands is attracting considerable attention in that country. The recent discoveries at Beaumont, Tex., have given rise to the hope that oil in paying quantities will also be found in Mexico. Very favorable indications of its presence have been discovered at several places, and liberal concessions for the development of petroleum deposits on national lands have recently been granted by the Federal Government to prospectors.

Almost certain indications of the existence of petroleum are to be seen in

many States, and especially in Tamaulipas, where in places there is an abundance of asphalt, sulphur and oil on the surface. Besides these signs, some of the topographical features, according to the opinion of an expert engineer and oil prospector, are due to the great pressure of the confined natural gas beneath. In most cases, the exudation does not consist of any one substance in a paying quantity, but passes through all the grades, from an inferior, dark-colored oil to massive hard asphaltum rock. There are also other equally encouraging indications of an abundance of gas and oil in the shale below.—*Engineering and Mining Journal.*

THE ARTIFICIAL PRODUCTION OF PRECIOUS METALS.

For over a thousand years mankind declared and believed that gold and silver could be artificially produced, and innumerable searchers have labored on this problem. These workers have not been wholly within the class of metallurgists or what we might call scientists, but all ranks and callings have contributed contingents. The general impulse which we designate as alchemy remained influential until the beginning of the eighteenth century, and was so widespread that it deserves consideration by a student of social science. While it is probable that in the more ignorant ages a larger number of persons believed in incantations and ghosts than practised true alchemy, yet the public profession of the latter was much more frequent than the public profession of supernatural powers. The history of alchemy has indeed less significance for chemistry than for the history of culture.

The belief in transmutation was promoted by the observation of cases in which the appearance of gold and silver could be imparted to baser metals. For example, copper alloyed with zinc assumes the ordinary color of gold. Treated with certain arsenical substances it assumes a silverlike appearance. Moreover, the doctrine of Aristotle, that substances differ not because of different composition, but by reason of difference of properties, necessarily encouraged the transmutationists. It was in this spirit that one operator distilled mercury seventeen hundred successive times in hopes of driving out from it the liquefying principle and thus obtaining the solid silver.

The ignorance as to the details of chemical composition also led to another misunderstanding. Mine waters containing copper compounds (the existence of copper as such in the water was not recognized) would, by the action of iron, deposit the copper and the iron would dissolve. We have no difficulty to-day in comprehending the nature of the action, but there was a time when it was believed to be transmutation, and in alchemical language was expressed as being due to Mars (iron) having laid off his armor and decorated himself with the garments of Venus (copper).

It is interesting to note also that, according to the Greek alchemists, lead was the generator of other metals. It was especially the generator of silver. We have no difficulty in understanding how this last error arose. Lead ores usually contain some silver, often very considerable amounts, and the operation of cupellation easily burns off the lead and leaves the button of silver, in which small amounts of gold are often found.—Henry Leffmann, in *Cassier's Magazine.*

Mining and Metallurgical Section.

Read at the Stated Meeting, held Wednesday, December 11, 1901.

Upon the Structure of Metals and Binary Alloys.

By William Campbell, B.Sc. (Durham), F.G.S.

(*Continued from p. 16.*)

Fig. 10 shows the surface-structure of a bar of aluminium. Two intersecting dendrites are seen. In each only one quadrant has developed. We have two axes at 90°, and from each grow parallel branches normal to their own axis, but parallel to the adjacent axis. From these branches grow leaf-like grains, thus forming a true skeleton crystal. The whole shows a decided cubic character. The cubic structure of aluminium can be clearly shown by casting a small ingot of the metal. When half solid, the ingot is tilted and the liquid part is allowed to drain off. The rough surface thus exposed is seen to be divided up into many areas; each area is made up of a number of small cubes similarly orientated, whilst each cube is made up of row upon row of minute grains. The whole structure resembles a surface of silicon steel (4½ per cent.) in Stead's Crystalline Structure of Iron and Steel.*

Copper, platinum, gold and silver show this dendritic structure on their surfaces when suitably cooled. *Fig. 11* shows the structure met with on the surface of a cupellation button of silver. Only the center of the skeleton crystal is shown, but the two main axes can be seen at right angles to each other; from each grow out, normally, parallel rows or branches composed of grains. The nearer to the center of crystallization, the smaller are the grains. In *Fig. 12* a smaller skeleton crystal is shown. It is similar to the large ones, but is stunted in growth. It shows the curious growth at the ends of the axes where they merge into the

* *Iron and Steel Institute*, May, 1898.

surrounding surface. Although these skeleton crystals are fairly common, they do not occur on all silver buttons. The normal structure of the surface of a cupellation button of silver is shown in *Fig. 13*. It consists of grains with straight boundaries. This structure is probably the result of contraction on solidification, because, in places, the lines are seen to cut across patches of similar orientation, *i. e.*, crystals. The true area of each grain (crystal) is seen by its orientation, and the lines of fissure generally coincide with the true grain (crystal) boundary because these will be the lines of weakness. In some cases, however, they take a direction of their own. This cooling structure is probably similar to that met with in many basalts. The surface structure of a silver ingot is seen in *Fig. 14*. There are several large grains or crystals with irregular boundaries but distinct orientation, each made up of secondary grains, similarly arranged, causing that orientation.

In the case of bismuth, *Fig. 15*, we see that the dendrites are inclined to assume a definite crystalline form; and this is exactly what we should expect when we remember the definite forms seen on a crust from a crucible of bismuth. The stars of antimony are too well known to require any description here.

When certain metals are cast, dendrites are formed by the shrinking of the liquid part during solidification, thus leaving them standing above the surface. A similar thing occurs when many alloys are cast. We may have dendrites of a metal left in relief, due to the shrinking of the eutectic or portion of the alloy which solidifies last; or we may have definite crystals, generally of a compound, standing up above the surface. These surface structures, as we said before, are often very reliable indications of the internal structure of the alloy. They may also be very misleading, however, as in the case of the bronzes between 70 per cent. and 95 per cent. of copper.

In his paper on the "Crystalline Structure of Iron and Steel,"* Stead points out that the same law which deter-

**Iron and Steel Institute*, May, 1898.

mines the size of the individual crystals formed when hot saturated solutions of chemical salts are cooled quickly or slowly holds good when metals solidify from the liquid state. If a metal be cooled very slowly past its freezing point, its structure will be comparatively large; if it be cooled rapidly past its freezing point, the result will be a much finer or more minute structure. In cooling slowly, crystals start to grow from a comparatively few points only, and the resulting structure is large; in rapid cooling, the points of initial crystallization are numerous, and the structure on complete solidification is small. When a crystal starts from a point it grows in all directions till interfered with by the growth of adjacent crystals. As the crystals seldom grow so that their crystallographic axes lie in the same directions, we find on solidification that each has a different orientation. This difference in orientation is beautifully seen if we take ingots of lead, tin, cadmium, zinc, etc., and lightly etch their surfaces. The effect of etching is to take off the surface of the metal, but not as a film of uniform thickness. The acid has not the same effect on each crystal, but removes more of one than of another, the amount depending upon the position of the crystal with relation to the surface which is being etched. The acid follows the track of the secondary crystals, or rather grains, and so we have a step-like surface eroded, which resembles, more or less, a broken surface of galena. Thus, light is more or less reflected from each crystal, depending on the angle at which the step-like surface is inclined.

The size of the crystals of an ingot of metal and, to a great degree, their shape depend upon the mould in which the metal is cast. Thus tin, when cast in a stone mould, gives quite a different appearance to what it does when cast in iron; the difference, of course, being due to the difference in rate of cooling. Again, the size of grain or crystals depends upon the purity of the metal used. If pure and impure tin be cast in the same mould, in the case of the impure tin the crystals will be comparatively long and slender, their length pointing towards the axis of the ingot.

The fractures of ingots in general reveal a columnar

structure. If an ingot of zinc be broken, elongated crystals with irregular faces are seen to have grown from the surface next to the mould perpendicularly towards the center of the ingot. If a section of an ingot of lead or tin be cut vertically, polished and etched, a similar structure is seen. If ingots of lead are broken hot, this columnar structure is beautifully revealed, whilst cast cylindrical rods of most metals show a radial structure, due to the same cause. On fracturing a cast rod of antimony the structure is that of numerous elongated pyramids with their apices meeting at the axis of the rod, their bases forming the cylindrical surface of the rod.

THE EFFECTS OF STRAIN.

The effects of strain upon metals has been well explained and illustrated microscopically by Ewing and Rosenhain.* Charpy† has illustrated the effects of strain and also of annealing upon the brasses, etc.; Roberts-Austen‡ upon steel rails and gun tubes.

Ewing and Rosenhain state that no effects of strain can be detected under the microscope within the elastic limit; but as soon as this is passed, fine dark lines are seen on the faces of the grains. They are more or less straight, are parallel in each grain, but are differently orientated in different grains. The first lines that appear are those approximately transverse to the line of force; but as the force increases, other systems of lines appear on other grains, and these lines are inclined to the direction of straining. As the straining increases some of the grains begin to show one, two, three and more systems of parallel lines, thus giving the grain the appearance of Schillerization. If the surface of a bar of bismuth, which has been strained till it broke, be examined, the lines or slip-bands are clearly seen on each side of the fissure. Several parallel groups will appear in view. *Fig. 6* in Dr. Mathews' paper showed some of these

* Bakerian Lecture, May 18, 1899, *Phil. Trans. Royal Soc.*, cxciii, p. 353.
† *Bull. de la Soc. d'Encouragement.*
‡ *Journal Iron and Steel Institute*, No. II, 1898; No. II, 1900.

slip-bands in tin. It shows the strained surface of an ingot of pure tin, whilst *Fig. 5* of the same paper showed lines of strain set up in a section of tin which had been hammered and then annealed. Similar slip-bands in crystals of cadmium are shown in *Fig. 8*. The cry of tin, the crackling of zinc, etc., are due entirely to the formation of these slip-bands.

It was mentioned above that when a soft metal, such as lead or tin, was cut with a file, particles tend to cling to the file and tear the surface of the metal. A similar thing happens with nearly all the softer alloys. The immediate effect is not noticed; but on etching, long parallel lines of irregular grains or crystals are seen to have been developed. *Fig. 3* shows such lines developed in tin. When a soft metal or alloy is cut with a saw, a similar crystallization is set up, and unless the metal thus modified is removed during subsequent treatment, this crystallization appears along with the original structure on etching. *Fig. 4* shows a section of slowly cooled tin which has been cut with a saw; a finer crystallization is seen together with the larger structure, due to the original cooling. If etching be prolonged the finer structure is obliterated, showing that it is only on the surface.

Now, when a piece of metal is hammered or rolled the crystals become lengthened in the direction in which it has become drawn out, and shortened in the direction of contraction. In the case of copper, iron and other of the tougher metals, this attenuating stage is of comparatively long duration; but in the case of the softer metals it is short and the crystals or grains break up to form a new and minute crystallization. *Fig. 2* of Dr. Mathews' paper shows the appearance of hammered tin. The structure is roughly granular and no trace of the original slow-cooling structure can be seen as in *Fig. 4*. Rolled tin has a similar structure, and it is curious to note that the thinner the piece is rolled the more distinct become the individual crystals. At a certain point they no longer split up, but become attenuated as if plastic. The structure of rolled cadmium is shown in *Fig. 6*.

THE EFFECT OF HEAT-TREATMENT.

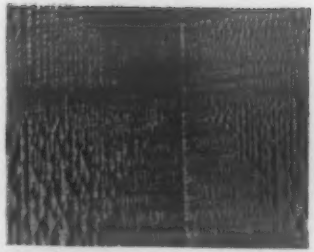
It is well known that annealing tends to relieve the strain in a metal or alloy. In many metals it does more than this; it causes the growth of crystals or grains. *Fig. 1* of Dr. Mathews' paper shows a bar of tin rolled out to about 3·5 millimeters thick. The right-hand pair show the structure of the metal just as it comes from the rolls. The left-hand pair have been annealed for ten days upon a hot-plate at not more than 180° C. The size is slightly reduced. The difference between the unannealed and the annealed specimens is striking to say the least. The orientation in the left-hand pair is marked and shows the boundaries between the various crystals. *Figs. 3* and *4* of the same paper show hammered tin unannealed and annealed at about 180° C. for seven days on a hot-plate (not ten days as stated). Again the difference between the two specimens is striking. In *Fig. 4* it will be noticed that the new crystals tend towards straight regular boundaries and in section are more or less perfect hexagons.

Fig. 5 shows five pairs of strips of cadmium rolled out from a rod. Starting from the right, the first pair have a thickness of 0·075 inch, the second of 0·049 inch, the third of 0·036 inch, the fourth of 0·024 inch, whilst the last and thinnest pair are only 0·018 inch in thickness. They were rolled out from a rod having a circular section $\frac{5}{16}$ inch in diameter. Their length is $2\frac{3}{8}$ inches and breadth 0·4 to 0·45 inch.

The right-hand strip of each pair has been annealed for seven days in an air bath at a temperature under 180° C. Etching in all cases was with nitric acid dilute. After rolling, the thickest pair (No. 1) were found to have the coarsest structure and this is shown in *Fig. 6*. After annealing, although tolerably large crystals were found in all of the strips, the thickest strip was found to have the coarsest average grain. *Fig. 7* shows the crystals developed in No. 3 by annealing. The definite boundaries and distinct orientation are to be noted. Those developed in No. 1 were so large that a single crystal would cover the whole figure at the same magnification, whilst those developed in the thin-

9. x 33. v.

10. x 33. v.



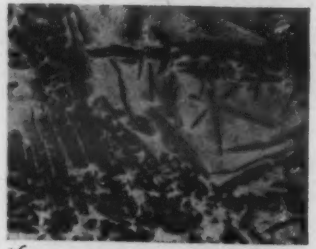
11. x 33. v.

12. x 33. v.

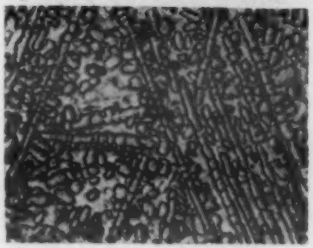
13. x 16. v.

14. x 33. v.

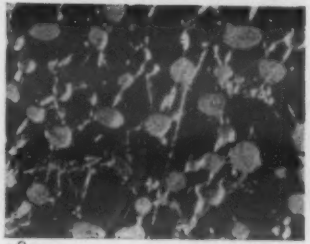
15. x 33. o.



16. x 33. v.

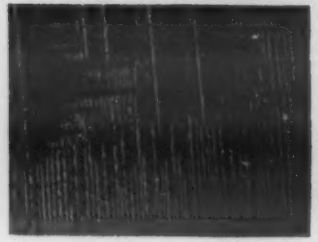


17. x 33. v.



18. x 33. o.

19. x 33. o.



20. x 33. v.

21. x 56. o.

22. x 33. o.

23. x 33. v.

24. x 30. v.

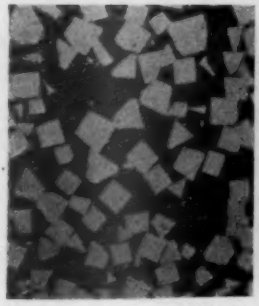
25. x 56. o.

26. x 33. v.

27. x 33. o.

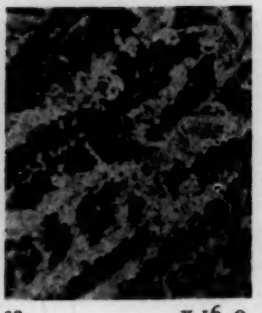
28. x 33. v.

29. x 16. v.



30. x 33. v.

31. x 33. v.



32. x 16. o.

nest strip were proportionately smaller. *Fig. 8* shows some of the smaller grains or crystals of No. 1, photographed after the strip had been bent. The strain produced by bending has set up the series of slip-bands. Five distinct parallel series can be seen in the largest grain on the left.

An exactly similar experiment was performed with tin. The annealing was carried on for five days on a hot-plate and the results were identical with those of the cadmium. In both cadmium and tin, annealing produces a marked brittleness, and when the strips are distorted they cry.

If ordinary rolled sheet lead be etched and examined, a structure similar to *Fig. 6* will be met with. Etching is best performed with acetic acid for a long period. Anneal it for a week at a temperature of only 200° C., and a coarse, very irregular crystalline structure will be developed. The crystals will be of all sizes and shapes; in many, distinct twinning will be observed. In all cases the difference in orientation will be marked. In one case a crystal quite 1 inch long by ½ inch in breadth was grown in five days by the author. The temperature was only 180° C. and the thickness of the sheet of lead 1·75 millimeters.

Take zinc and roll it out into strips; it will take a fairly high power to reveal its structure. Anneal it as before shown and you will find the crystals have grown so large that some two dozen will be all that are able to occupy your strip. The rolled zinc will be exceedingly tough, but after annealing it will crackle on bending ever so slightly and will break if further bent, for annealing has made it extremely brittle. On slightly bending it and then examining it under the microscope, it will be seen that each grain is traversed by parallel systems of slip-bands, which develop into cracks if the bending be carried to any considerable extent.

If the surface of electrolytically deposited copper be examined, a coarse crystalline structure is seen. On parts of the sheet it will often be found that the rate of deposition has been greater than the surrounding surface and a crystalline knob of copper stands out above the level of the rest of the sheet. If a section be made through one of

these knobs, and the surface be polished and etched, the true crystalline structure is shown up. It consists of comparatively large, irregular crystals, each possessing a definite orientation. If this copper be rolled out, the large crystals are broken up and a much finer crystallization is set up, still composed of crystals with irregular boundaries. If copper foil be examined after its repeated annealing and rolling, or rolling alone, it is seen to be composed of very small grains. The foil possesses a marked amount of spring. No amount of etching will show any orientation and the structure seems to be composed entirely of oval grains, pointing, of course, in the direction of rolling. It is similar to that of sheet-copper which has been rolled out from an ingot. Anneal it for a moment at a straw heat and it becomes quite limp with no trace of spring left. On examination the fine crystalline structure has disappeared and a large mottled structure is now seen. Thus there is an intimate relation between the fine rounded or oval-grained structure and elasticity of the copper foil.

Electro-nickel when polished and etched shows a reniform structure where it has formed a knob-like mass. Numerous distinct layers can be seen, but, so far, no distinctly crystalline structure can be seen. The structure of iron appears to be similar to that of nickel, that is, it consists of layer upon layer like an agate. The effects of annealing and rolling electro-nickel and iron have not been examined as yet by the author.

The growth of crystals in the solid due to annealing has been shown over and over again. Roberts-Austen, in his last Cantor Lectures, delivered to the Society of Arts, London, exhibited three photomicrographs showing the growth of crystals in pure gold. The first showed two plates of pure gold pressed together. The squeezing was so great that the crystals had been strained. Without strain, it is thought that no welding will take place. The second view showed the plates after annealing at 750° C. and slowly cooling. The junction between the two plates could be distinguished, but in several places crystals had grown across the junction. A third view showed the same after long

annealing and the line of junction had entirely disappeared. If a section be taken across a weld in a steel rail or bar which has been joined by the Goldschmid welding process, no line of junction can be seen.

ALLOYS.

Under the heading of "Alloys as Solutions," Dr. Mathews points out that certain metals when liquid at ordinary temperatures do not mix or alloy, and on standing separate into two layers, the heavier at the base.

The following are some of Dr. Alder Wright's figures, obtained by taking each of the five pairs well mixed by stirring, and then allowing them to stand molten for some hours at 800° C.; separation took place; two liquid alloys were formed; these were quenched and each analyzed.

In the case of zinc and lead, the heavier alloy contained 1·3 per cent. Zn; the lighter 1·57 per cent. of Pb.

In the case of zinc and bismuth, the heavier alloy contained 14·28 per cent. Zn; the lighter 2·32 per cent. of Bi.

In the case of aluminium and lead, the heavier alloy contained 0·07 per cent. Al; the lighter 1·91 per cent. of Pb.

In the case of aluminium and bismuth, the heavier alloy contained 0·28 per cent. Al; the lighter 2·02 per cent. Bi.

In the case of aluminium and cadmium, the heavier alloy contained 0·22 per cent. Al; the lighter 3·39 per cent. Cd.

If we allow our molten metal to cool down very slowly till it solidifies, and then examine the two alloys thus formed, in the case of zinc and lead or aluminium and lead, and most probably also of aluminium and bismuth or aluminium and cadmium, we get the same results. Each alloy is a solid solution of one metal in the other; no crystals but those of the metal in excess can be seen. Take the aluminium-cadmium pair. The structure of the upper part is that of aluminium, and all of the cadmium it contains is in solid solution. The structure of the base is that of cadmium, and all the aluminium in it is in solid solution. In the case of the lower alloy of the lead-aluminium pair, it is probable that the lead throws all of the aluminium out of solution before solidification, because, according to

Heycock and Neville, the freezing point is not depressed at all.

With the zinc-bismuth pair matters are different. The upper alloy shows zinc containing all the bismuth in solid solution, but the lower one shows a fine crop of crystals in a groundmass, which is probably a eutectic of bismuth and zinc, as is shown in *Fig. 16*. Thus between bismuth and about 13 per cent. Zn, 87 per cent. bismuth, we get one layer in each alloy we make. Between these points we have a simple series of alloys, whose freezing-point curve consists of two branches inclined to each other and meeting at the eutectic point 3·5 per cent. Zn at about 240° C.*

If either of the five pairs of metals above be melted and a sufficient proportion of either tin, silver, antimony or copper be added, no separation will take place; but if the quantity of the "solvent" metal is less than a certain amount, the alloy separates into two layers, each layer consisting of a ternary alloy of the three metals. *Fig. 17* shows a case where sufficient of the "solvent" metal was added and a single ternary alloy was formed. The alloy consists of equal weights of zinc, bismuth and tin. The figure shows long dendrites, which closely resemble those of zinc in zinc-tin alloys, set in a groundmass, probably a triple eutectic of BiZnSn.

In many text-books the amounts which each of the above pairs of metals retain of the other when solid varies widely. In some cases we are told that aluminium mixes freely with both bismuth and cadmium. The reason for this lies in the method of cooling. If instead of cooling slowly we cast or chill our alloy, directly after stirring, we don't allow our emulsion to settle, and in consequence *globules* of the heavier are found in the lighter alloy. *Fig. 18* shows the surface of aluminium containing such globules. Aluminium was melted with some Bi and Cd. When thoroughly melted the pot was shaken and the alloy poured into a cold iron mould. In consequence of the rapid cooling, separation

* Gautier: *Bull. de la Soc. d'Enc.*, Vol. I, 1896, p. 1293. Roberts-Austen: "Introduction to Metallurgy," plate pp. 114–115.

could not take place, and scattered throughout our aluminium appear shots or globules of the bismuth-cadmium alloy. When slowly cooled perfect separation took place.

BINARY ALLOYS.

Charpy* has published one of the most complete papers on the microstructure of binary alloys. He classes them according to their curves of fusibility, following Le Chatelier.

Group I.—Two branches of curves starting from the melting-points of the two pure metals and meeting at a point corresponding to the eutectic alloy; this curve is obtained when the metals form neither definite compounds nor isomorphous mixtures.

Group II.—Three branches of curves, two of them starting from the melting-points of the pure metals and a third exhibiting a maximum and crossing the two former in two points corresponding to two eutectics; it is the case of two metals forming a definite combination.

Group III.—The curve of fusibility is continuous and unites the melting-points of the two metals forming isomorphous mixtures.

Fig. 14 in Dr. Mathews' paper shows types of these curves. Group I is represented by the AgCu curve, Group II by the SbCu curve, and Group III by the AuAg curve.

To Group I belong all those alloys in which the excess of either metal crystallizes out in a eutectic which is a mechanical mixture of the two metals.

Tin and zinc.	Lead and silver.
Tin and lead.	Zinc and aluminium.
Tin and bismuth.	Copper and silver.
Lead and antimony.	Copper and gold.

Dr. Mathews' explanation of *Fig. 18* of his paper holds good in the case of all the above alloys, the only difference being that in some cases the compositions *b* and *d* represent comparatively large figures, as for example in the case of copper and silver or copper and gold; in some cases *b* and *d* represent compositions of solid solutions infinitely dilute;

* *Bull. Soc. d'Encourag.*, March, 1897.

that is, b and d are numerically very small, as in the case of tin and zinc, etc.

We can form a sub-group in which the excess of one metal crystallizes out in a eutectic which is a solid solution of this metal in the second.

Aluminium and tin.

In Group II we get two divisions for each pair of metals alloyed, each division being comparable with Group I, thus:

(1) The excess of the first metal or the compound crystallizes out in a eutectic which is a mechanical mixture of this metal and the compound.

(2) The excess of the second metal or the compound crystallizes out in the second eutectic, which is a mechanical mixture of the second metal and the compound.

Copper and antimony.
Tin and nickel.

A sub-group might be formed in which the eutectics are solid solutions of the compound in either the first or the second metals.

Antimony and aluminium.

Thus we get two divisions, each of which is comparable with the sub-group of Group I. In the case of antimony and aluminium we have the compound SbAl crystallizing out in a eutectic which is a solid solution of Sb in Al, or in a eutectic which is a solid solution of Al in Sb.

[*To be concluded.*]

ARC LAMP CARBIDE ELECTRODES.

A patent granted May 20th to Robert Hopfelt, of Berlin, Germany, describes several forms of a new type of electrode for arc lamps. In each case the material of the electrode consists of calcic carbide, coated with a water-proof compound or sheathed with a metal such as aluminum. It is stated that metallic carbides, such as calcium carbide, gives a much more powerful arc than do ordinary carbon electrodes, but that this material has not been employed in arc lighting heretofore because of the decomposition incident to the presence of moisture in the air. By covering the surface of the carbide with a layer impervious to moisture, it is claimed that this objection is obviated. In another form of the electrode there is a cone of metallic wire, and in still another form, a core of carbon dust. A solid electrode is also described, consisting of a mixture of carbon and carbide.—*Electrical World.*

Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.*]

The Beaumont Oil Field, with Notes on Other Oil Fields of the Texas Region.

By Robert T. Hill, Washington, D. C.

INTRODUCTORY.

The successful completion, January 10, 1901, by Capt. A. F. Lucas, of a well near Beaumont, Tex., whereby an enormous flow, estimated at 75,000 barrels a day, was obtained, opened a new oil-field in the United States, kindled a frenzy of exploitation and speculation, revolutionized the fuel industry of a large region, and brought gain to thousands of people.

Even to-day, it is impossible to cast up the present results or to prognosticate the future influence of this event. It has caused the revival of attention in other localities where oil had been suspected and exploitation for oil throughout the Texas region. It has attracted attention to the mineral resources of the Texas region, and created an interest in the geological conditions of that great State.

This State, which has increased in population and wealth, as recorded by every succeeding census, with leaps and bounds such as are exhibited by no other part of the Union, now stands fifth in population and first in productive wealth *per capita*. Its fields, pastures, forests and mines teem with raw material. The whole economic evolution of the State has gravitated toward a focal point where these products were available for the coming of the kiln, the machine and the factory.

The only drawback to the prosperity of the State was the lack of an economic fuel, inferior coal costing an aver-

age of $5 per ton at the time of the Beaumont discovery. This prevented the successful operation of any one of the thousands of minor industries upon which other communities ordinarily depend for prosperity. As by a touch of magic, this great fuel supply burst forth in a single day, thanks to Captain Lucas, who, aided by the wise laws of the railway commission, placed at the fireside of every citizen, at every quarry, clay-bank, sandpile, mine and mill, the cheapest and best of fuels.

With these factors in hand, who can even grasp the significance of the great industrial development which is to take place within that empire during the next decade? Who can conceive the countless wheels to be set in motion? Who can reckon the prospective increase in population, the municipal development, the opening of brickyards, factories, shops and mills? Never before in history has there been such a culmination; never again will such opportunities be presented for the man of energy as means are now presented in Texas.

THE LIMITATIONS OF GEOLOGICAL INTERPRETATION OF OIL-PHENOMENA.

In endeavoring to interpret the geological occurrence of oil, the geologist is confronted by the fact that science has not yet solved the problem of its origin, which lies at the root of the subject.

Among the theories in this field are those of inorganic chemical origin, resulting from reaction of one mineral upon another; the generation of oil in living microscopic organisms, such as diatoms; and the generation of oil from the decomposition and deterioration of dead organic matter, animal or vegetal, preserved in the rocks. There are facts in nature which can be made to conform to either of these theories; but for the present we must consider oil as a material in the rocks, the origin of which is still unexplained.

Concerning this occurrence, we can only say that each field where it is discovered presents a peculiar group of data, some of which may, or may not, be presented in others.

It is well known that certain strata, like shales, with large admixture of organic matter, are nearly always more or less bituminous, and are probably the *locus* of the original formation of oil from decomposition of the organic matter. On the other hand, the oil in commercial quantities is usually found in some adjacent bed, like an overlying stratum of sand, which forms a more porous receptacle. Where such shales and sands are in proximity, the oil is practically indigenous; and such occurrences may be termed sheet-oil. In other cases, oil is found in pockets, in strata which do not contain sufficient bituminous matter to justify the reference of its origin to them. Such occurrences may be termed pocket-oil.

Science has ascertained much concerning the underground circulation of water, but we know very little concerning the laws controlling the underground circulation of oil. The few elementary physical facts concerning the behavior of oil and water teach us some lessons. From the antithetic behavior of the water and the oil upon the surface, we can with safety presume that these substances will not act in an entirely harmonious manner underground. We know that oil will float upon water, and therefore that circulating underground waters, if ascending, may gather oil from places of its origin, and transport it and store it in remote underground reservoirs. On the other hand, oil differs from water in capacity for permeation and osmosis. Oil stored in a tightly sealed bottle will pass by osmosis through the glass more rapidly than water. The question of the underground migration of oil is one of the profound fields for future research.

The principal deductions from the world's experience concerning the occurrences of oil are:

(1) The chemical origin of oil is as yet unexplained.

(2) Oil may occur in stratified rocks of any age from the oldest Paleozoic (as in Pennsylvania) to the latest Tertiary (as in Texas).

(3) Oil usually occurs in terrigenous (land-derived) marine deposits, such as sands and clays, in which there is a mixture of organic matter, and is not common in rocks of deeper

sea origin, such as many of the foraminiferal limestones, or igneous rocks.

(4) The circulation of oil in rocks is different from that of water.

(5) The structure or arrangement of the rocks influences the collection and storage of oil, and hence the knowledge of geological structure aids in the determination of favorable or unfavorable conditions for the underground storage of oil.

(6) Some underground bodies of oil are known to be stored in, or even to be derived from, definite strata. The trained geologist can indicate the underground extent ("embed") of such strata.

(7) Other underground oils are stored in favorable *loci* more or less remote from the strata in which they originated, and accumulated in folds or pockets, like water in a rubber blanket (the blanket being inverted).

The above facts indicate what the geologist can and cannot tell concerning oil-fields. The first thing he can do in the great region is to eliminate or cancel broad areas of unfavorable strata, leaving certain fields of probability and improbability. Within a determined field of probability it it impossible to predict the actual point where oil can be found. The cost and credit of developing the oil-field must always ultimately fall upon those who boldly risk labor and money upon what is largely a game of chance.

The practical geologist has to deal primarily with the stratigraphic location of oil, the deformations of strata favoring the collection of this oil in geological receptacles, and the laws of underground circulation of oil in the rocks.

Where a determined oil-field is underlaid by sheet-oil, the probabilities of success are greater, and the geologist can assist the practical man with some confidence. On the other hand, where the oil-field consists of pockets, no one knows as yet how to locate these pockets beneath the surface.

The oil-bearing strata of the Beaumont oils are entirely different from those of the Corsicana oil-field (where the oils are derived from the Upper Cretaceous strata); from the

Indian Territory oil-fields (where the oils are derived from the Carboniferous strata); and from the oil-fields of Pennsylvania, Ohio and West Virginia (which receive their oil from the still older Paleozoic rocks, such as the Trenton).

The prospector in the Beaumont oil-field must be prepared to cast aside previous conceptions based upon the structure and age of the earlier-known oil-fields.

GEOGRAPHY OF THE TEXAS REGION.

In a recent paper* the author presented an outline of the physiographic features of the Texas region, as shown on a map therewith, and defined its earliest primary natural subdivisions as a basis for more detailed discussion and differentiation of the various phenomena.

The Greater Texas region includes practically all the country east of the Rio Grande and south of the northern boundary of New Mexico. The area thus defined consists of a peculiar group of physiographic units, composed of mountains and plains belonging to the four greater natural provinces of the United States, to wit: the Cordilleran region, the Great Plain region, the Appalachian region, and the Atlantic Coastal Plain. The characteristic features of these regions as they extend into the State present local modifications. There are also in the central portion extensive stretches of country which have no counterpart elsewhere.

It is impossible to give here the details of the varied geographical features of this vast area, which includes nearly one-tenth (Texas proper embracing one-twelfth) of the present area of the United States. In another paper† I showed the rapid evolution which the economic features of Texas have undergone in the past twenty years from the pastoral to the industrial conditions, and declared that the one great need of the State was an economic fuel. Almost coincident with the publication of that paper was the completion of the great oil-wells at Beaumont.

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* "Physical Atlas of the Texas Region, U. S. Geological Survey," 1901.

† See *Forum*, August, 1901, and *Encyclopædia Britannica*, London *Times-Supplement*, 1902.

The adjacent ascertained oil-yielding territory of the State, with its probable extension into adjacent States, is indicated on accompanying sketch-map, *Fig. 1.*

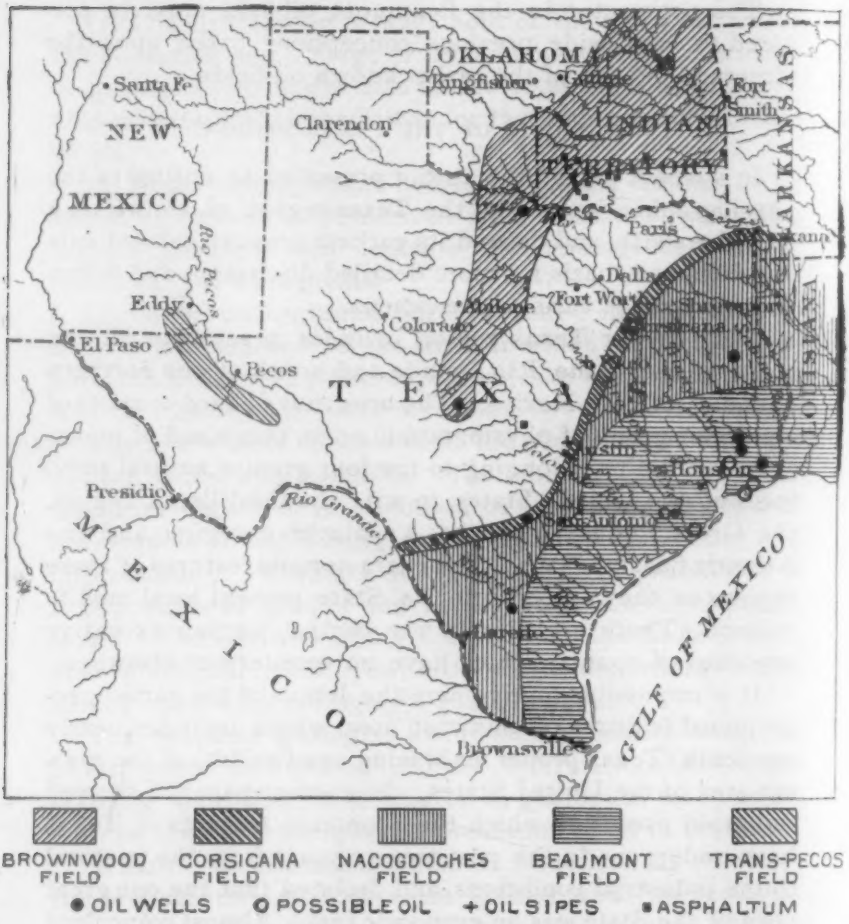

FIG. 1—Map of the Texas oil region and adjacent oil-bearing territory.

SEDIMENTARY ROCKS OF THE TEXAS REGION CONNECTED WITH THE OIL-PROBLEM.

Most of the surface of Texas is formed of sedimentary rocks, igneous formations covering less area. There are

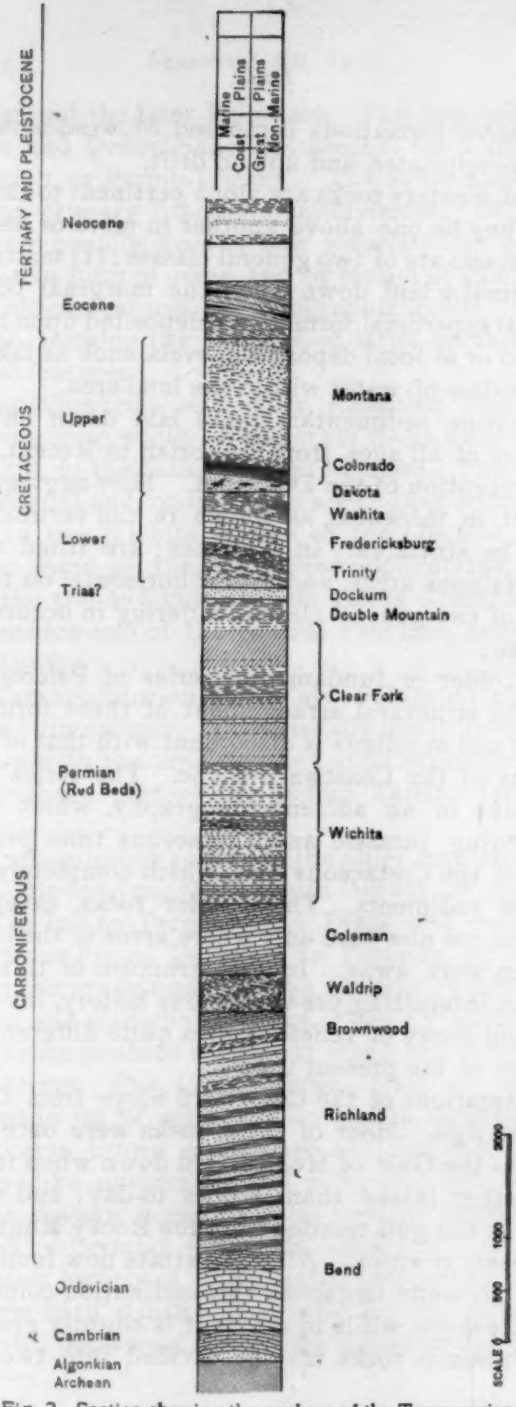

Fig. 2 Section showing the geology of the Texas region.

also extensive formations composed of wind-blown *débris*, chemical precipitates, and upland drift.

The sedimentary rocks are alone pertinent to the present paper. They lie one above another in more or less orderly succession, and are of two general classes: (1) marine formations, originally laid down upon the marginal bottoms of the sea; (2) superficial formations, deposited upon the slopes of the land or at local deposition-levels, such as lakes, rivers or other bodies of water within the land-area.

The marine sedimentary rocks laid down on the sea-bottoms are of all ages, from Cambrian to Recent, with the possible exception of the Devonian. They aggregate about 25,000 feet in thickness, as shown in the vertical section, *Fig. 2*. The strata vary in hardness; are tilted steeply in the mountainous areas, and nearly horizontal on the plains. They are of two general classes, differing in occurrence and importance:

(1) An older or fundamental series of Paleozoic formations. The structural arrangement of these formations in anticlines and synclines is discordant with that of the later formations of the Coastward Slope. The series represent the remains of an ancient topography, which was base-leveled during Jurassic and Cretaceous time, prior to the invasion of the Cretaceous seas, which completely buried it with later sediments. These older rocks, except in the mountains, are now seen only where areas of the later strata have been worn away. In the structure of this group is written an interesting pre-Cretaceous history, involving the growth and decay of relief-features quite different in detail from those of the present time.

(2) Formations of the Coastward Slope from Cretaceous to Recent Age. Most of these rocks were once marginal deposits of the Gulf of Mexico, laid down when it extended much further inland than it does to-day; and they were elevated as the gulf receded from the Rocky Mountain front to its present position. All these strata now incline toward the sea. In some instances the inclination coincides with the surface-slope, while in others it is slightly greater.

The Paleozoic rocks may be divided into two groups—

the earlier and the later Paleozoic. The first includes the Cambrian and Ordovician; the second, the Carboniferous and Permian, or Permo-Triassic. The same names characterize four primary lithologic subdivisions. Of these, the first two are usually more or less associated in geographic occurrence in limited areas, and by reason of their hardness produce allied features of topographic relief. The third and fourth, forming the surfaces of large areas, have each individual features.

The pre-Cambrian and older Paleozoic rocks are the foundations upon which all the other rocks were laid down, and are still, in the main, covered by them. Their outcrops are exceptional and restricted in area; they occur in small districts in the Wichita Range of the Ouchita Mountain system, in some of the trans-Pecos Mountains, especially between the 31st and 32d parallels, and in a limited territory in the southern end of the Central Province, known as the Burnet country.

The Cambro-Silurian rocks are indurated clays, sandstones and limestones. They usually occur in geographic association with the pre-Cambrian and Carboniferous rocks, in the southern part of the Indian Territory and Central Texas.

The Carboniferous rocks are the chief formations of the Ouachita Mountains, the eastern border of the Central Province in Indian Territory and Texas, and certain mountains of trans-Pecos, Texas. The Permian, or Red Beds, prevail in the greater part of the Central Province and in the Pecos and Canadian valleys. The Carboniferous and Permian rocks produce somewhat allied but different topographic forms. The Carboniferous (east of the Pecos), largely made up of soft, impure shales, alternating with harder, coarse brown sandstones and conglomerates, produce ridge-like mountains and a broken belt of country along the eastern margin of the Central Province, called "flats." The Permian Red Beds, some 7,000 feet in thickness, consist largely of unindurated arenaceous clays, with only a few hard strata. They weather into extensive flat regions with occasional scarp-lines attended by "bad-land"

slopes. They occupy the western and greater part of the Central Province, extend beneath the Plateau of the Plains, and outcrop in Pecos Valley against the eastern front of the Cordilleras.

The existence of the early Mesozoic (Triassic) is doubtful, although possible. Rocks referred to this period overlie the Permian along the western part of the Central Province, and appear in small areas around the border of the Plateau of the Plains, but are not pertinent to our present subject. Jurassic limestone strata of the Mexican type have been found in only a limited area in the basin-ranges of the interior desert, west of the Cordilleran front, and are not known on the Atlantic Slope or in the series of the Texas Coastal Plain.

The Coastward Gulf Slope consists of vast sheets of sea-made sediments, from Cretaceous to Pleistocene Age, inclusive, and of aggradational deposits of upland wash, and stream and lacustral alluvium of Tertiary and later age, all of which, except the lower Cretaceous, are mostly unconsolidated terranes of clay, sand, marl, and loam. Of this later group, the marine Cretaceous, Tertiary and Pleistocene rocks are the chief formations, especially east and south of the Central Province. These rocks occur in belts subparallel to the coast.

The Cretaceous rocks are divisible into older or lower and a newer or upper series. They occur along the western border of the Coastward Slope Plain. The older formations consist of hard limestones alternating with clays, and are underlaid by sands; they produce dip plains, cut plains, and low scarps. The Upper Cretaceous strata consist largely of unindurated clay marls, with a few indurated scarp-making strata all underlaid by sands, and weathering into low, undulating areas.

These Cretaceous strata, underlying the Coastal Plain of Texas, in the Black and Grand Prairie countries, have been minutely described by the writer in many papers, especially Part VII of the Twenty-first Annual Report of the Director of the United States Geological Survey. These consist of nearly 4,000 feet of shales and sands and limestones; prob-

ably one-half of the section is made up of marine near-shore clays and sands, and the remainder of deeper water limestones. The Cretaceous strata constitute the floor or foundation upon which the Tertiary and Pleistocene sediments were deposited, and most probably underlie the whole Coastal Plain of Texas at great depth, their base being not less than 10,000 feet deep along the coast at Galveston.

For present purposes the Tertiary may be divided into two great groups, a lower and an upper, which may be termed the Eocene and Neocene, respectively.

The Eocene strata consist of a series of unconsolidated sands and clays, accompanied by fossil shells and beds of lignite, and about 3,000 feet, more or less, in thickness. They have been considerably studied in a manner to make known their stratigraphy and character; but the nomenclature and classification are still susceptible of refinement. The writer prefers for the present to divide the rocks of the epoch into two series. For the older, including all the rocks from the base to the Nacogdoches oil-formation, he has already used the name Camden series. For the rocks above the horizon, the term Angelina may be used. While paleontologists are disagreed in their determinations, these names are good for tentative use.

The Camden series include many beds of clays, sand and lignite (underlying the East Texas timber-belt), for which various names have been proposed.*

The Angelina series, above the so-called marine beds of the Camden series, which are the first classified deposits immediately north of the Beaumont oil-field, have been described by Kennedy, in descending order, as follows:

(1) The Lufkin deposits (Yegua), made up chiefly of dark-blue gypseous clays, and gray sands containing quantities of saline matter. These beds also contain lignite, in many places, in beds or deposits of considerable extent.

(2) The Fayette sands, made up of soft sandstones, light-colored clays, sandy clays, and sands with occasional remains of vegetable life. These deposits approach in texture and

* See various reports of the Texas State Geological Survey.

mode of occurrence the typical Grand Gulf formations, as described by Hilgard, in Mississippi, and by Hopkins, in Louisiana. The plant-remains, such as palms, etc., are also in close correspondence.

(3) The Fleming beds (Frio clays) consist of heavy deposits of clays of various colors, some of them containing concretions of lime and gray sands. The plant-remains of these sands are chiefly wood, and often occur in large pieces and considerable quantities. The Frio clays are considered Eocene in Kennedy's later publications.

The sections made by Kennedy give the general character and sequence of the formations along a general section from Nacogdoches County to the Gulf.*

The thickness of the later Eocene (Angelina series) sections, as given by Kennedy, aggregates 1,407 feet.

Above the Frio clays of supposed Eocene Age follows a series of unconsolidated sands and clays of Neocene, Pleistocene and Recent Ages, which constitute the formation of the Coast Prairie. These will be further discussed on a succeeding page, under the head of the X beds.

Summarized, the post-Carboniferous strata beneath the Central Plain of Texas, and which by dip should be beneath the Coast Prairie, are as follows:

	Feet.
Post-Eocene	1,000 to 2,500
Eocene	3,500
Upper Cretaceous	2,000
Lower Cretaceous	2,000
Total	10,000

STRUCTURE OF THE RUDIMENTARY ROCK-SHEETS.

In general, the Paleozoic rocks of the northern border of the Ouachita Mountains of Indian Territory and the mountains of trans-Pecos, Texas, are greatly tilted as a result of the Appalachian revolution. Between the mountains the Paleozoic rocks in Texas occupy a great synclinal basin,

* Third Annual Rep. Geol. Surv. Texas, 1891, "A Section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico," by Wm. Kennedy, pp. 57, 58, 61, 62, 63.

dipping westward from their exposed eastern outcrops and eastward from their exposed western outcrops.

Over this synclinal basin, after a long land-period, the rocks of the Coastal Plain, from the base of the Cretaceous upward, were laid down unconformably. This unconformity is the most radical structural feature in the whole Texas sequence. It is not necessary for our present purpose to go further into the details of the structure of the Paleozoic rocks.

As a whole, these Cretaceous and Tertiary rock-sheets of the Texas Coastal Plain may be collectively discussed as the systems of the coastward incline, and their structure is very simple, the strata being characterized by their unconsolidated nature, their regularity of sequence, simplicity of arrangement, and gentle dip coastward.

One who begins at the coast and travels across this region along any line radial to the coast, will find that while the surface constantly ascends above the level of the sea at a slight gradient, it presents a descending geologic sequence in successive belts of country, each with its peculiar soil, rock and flora, due to the differences in the rock-sheets of which it is formed. The outcrops of the various strata, owing to their physical and chemical composition, have weathered into diverse characters of country—forest and prairie, broken or level—exactly as the substructure permits.

There are few, if any, breaks in the continuity of deposition of the 10,000 feet of sediments, of Cretaceous and later age, constituting the coastward outline. One of these apparently occurred at the middle of the Cretaceous, but without any special stratigraphic discordance. Another is supposed to have taken place at the close of the Cretaceous, but is not proved.

According to Kennedy, at the close of the period occupied by the deposition of the last of the marine beds of the Eocene, a break of considerable extent occurred; and extensive erosion, implying elevation, appears to have taken place prior to the deposition of the succeeding deposits. Strong proof of this erosion can be seen almost anywhere along the

line of contact where the succeeding denudation has carried off the overlying mantle of sand and gravel of the Angelina series. He says that this want of conformity is everywhere visible, and the clays and sands of the Grand Gulf frequently extend in long narrow strips for several miles into the region occupied by the Eocene marine formations; and at other places are found abutting bold headlands made up of the deposits of that age. Kennedy also informs the writer that there is a similar break at the top of the Angelina series.

So far as known, there are no strong folds or basins in the strata of the Coastal Plain, such as exist in the Ohio and Pennsylvania oil-fields, although there are probably some very low anticlines or swells, which materially bear upon the storage of the oil in the reservoirs or oil-containing strata. In general, the structure of the Coastal Plain is monotonously monoclinal.

The formations of the Coastal Plain are all marginal sediments of the Gulf of Mexico; and the present tilt coastward may be considered the algebraic sum of several periods of elevation and subsidence since the beginning of Cretaceous time, the net result of which is a sinking of over 10,000 feet at the present coast-line.

It is well known that in the epochs from the Pliocene to the present there have been several movements of elevation and subsidence, during which the shore-line of the Gulf of Mexico migrated back and forth. At times this shore-line was far inward from its present site, while at other times it may have been considerably seaward.

It is also probable that the stress resulting from the vertical movements of these strata caused faults, some of which are already known to have taken place along the western margin of the Coastal Plain.

[*To be continued.*]

Notes and Comments.

MANUFACTURE OF SULPHURIC ACID BY CONTACT PROCESS.

In the *Berichte der Deutschen Chemischen Gesellschaft*, xxxiv, pp. 4069 to 4115, was a paper by R. Knietsch on this subject, which will be of importance to all chemists who are interested in it. The great development that the catalytic manufacture of sulphuric acid has already attained in Europe is manifested by the fact that the Badische Anilin und Soda Fabrik alone produced 116,000 metric tons in 1900, against 89,600 in 1899 and only 39,000 in 1894. In the United States the process has already been undertaken by various acid makers, but so great progress has not yet been attained as in Europe. The theory of the process and the various methods of its application were described in *The Mineral Industry* for 1898 and subsequent volumes.

Phillips' application to the formation of sulphuric anhydride of the catalytic action of platinum, which was first observed by Sir Humphry Davy, 1817, dates back to 1831. Not much progress was made, however, until very recently, and the development of the present commercially successful methods was due to theoretical considerations, rather than to any practical results previously obtained. Experiments made with pure sulphurous anhydride and air showed that the practically complete conversion of SO_2 to SO_3 occurred, which proved also to be the case with the gas obtained by burning pyrite; but although the conditions of the laboratory experiments were exactly duplicated, it was found that the activity of the contact substance gradually diminished to zero. Investigation showed that certain impurities in the gas, especially arsenic, exerted a deleterious action on the platinum, very small quantities being sufficient to destroy completely the catalytic activity of the metal. The purification of the gas proved to be one of the most difficult problems in the development of the process; it can be effected only by intimate and thorough agitation of the gas with water or sulphuric acid, which must be continued until optical as well as chemical purity is reached.

The proper regulation of the temperature was found to be another essential feature. Inasmuch as the oxidation of sulphurous anhydride to sulphuric is exothermic, evolving 22,600 calories; and furthermore, since sulphuric anhydride is dissociated at a temperature between 900° and 1,000° C., it was seen that once the reaction was started extraneous cooling instead of heating was necessary. At a temperature below 200° C., however, there is no reaction. The maximum effect is manifested at about 450° C. It is important, therefore, for rapidity, to use a contact substance possessing its greatest activity at about 450° C. According to Herr Knietsch, the only known contact substance which fulfils that condition is platinum.

The packing of the asbestos is a matter of great importance; it must not be so loose that the gases can pass through without contact, nor so dense as to cause an improper resistance to the passage of the gases. The asbestos is best packed in layers on perforated plates, strung on an iron rod, kept apart by projections; in this way all the tubes of the apparatus can be similarly and evenly packed.

The best absorption medium for the SO_3 gas has been found to be acid containing 97 to 98 per cent. H_2SO_4; this is better than either water or acid of any other strength. A single absorption vessel is sufficient for even a very rapid stream of gas, if the strength of the absorbing medium be kept constant by the regular inflow of water and outflow of the sulphuric acid that is formed.

ELECTRIC FURNACE PRODUCTS AND THEIR POSSIBLE USES.

A symposium on electro-chemistry and electro-metallurgy was recently held by the American Institute of Electrical Engineers. C. B. Jacobs discussed some of the remarkable products of the electric furnace, of which calcium carbide is the best known. He suggests that calcium carbide may attain greater importance as a reagent in manufacturing chemistry than in the production of acetylene. It is a powerful dehydrating agent and may come into extensive use for extracting moisture.

The silicides of calcium, barium and strontium are formed in the electric furnace at somewhat higher temperatures than those required to produce the carbides. The silicides decompose with water and yield free hydrogen in a pure state.

It was said in the course of this discussion that these silicides promise to become important in the steel industries through their actions on sulphur and phosphorus. It is stated that by use of these silicides sulphides and phosphides are formed which are eliminated in the slag, and that an iron high in sulphur and phosphorus yielded by this treatment a steel from which the last traces of sulphur and phosphorus were removed.

GROWTH OF THE JAPANESE MERCHANT MARINE.

Food for thought is furnished by some figures which have recently been issued concerning the Japanese mercantile marine. It appears from a statistical statement published by the Japanese Minister of Communications that during the four years ending with 1901 the number of steamships in the Japanese merchant service had increased from 627 to 942, the number of sailing ships from 174 to 3,416, the tonnage of steamships from 429,774 to 557,166 and the tonnage of sailing ships from 24,014 to 315,576. In connection with these figures lies the fact that in 1896 Japan possessed only one merchant steamship of a tonnage exceeding 5,000 tons, but now that country possesses twenty-one steamers whose individual tonnage is above 5,000. The progress which has been made in the extension of its navigation interests by this country, which but recently won a place among civilized nations, is most surprising. At the same time it is a lesson worthy of study by a nation like the United States, so long in the forefront of enlightened nations of the world. We discuss ways and means for increasing our merchant marine service, and while we discuss, the people of Japan push forward. This enterprising Asiatic nation has made great strides in securing a stronghold on the transportation interests of the Pacific Ocean. Japanese vessels are among the largest and best equipped in the Pacific service. Unless the people of the United States take more interest in this matter and adopt practical measures to secure and retain a hold on the commerce of the Pacific Ocean, Japanese steamers will in time control the greater part of that business.—*Iron Age.*

Book Notices.

Text-Book of Physiological and Pathological Chemistry. By G. Bunge. Second English edition, translated from the German edition by Florence A. Sterling and edited by Ernest H. Sterling, M.D., F.R.S., etc. Philadelphia: P. Blakiston's Son & Co., 1902. (Price, $3.)

The high reputation of the author of this work as the leading exponent of the modern school of bio-chemistry has made his lectures familiar to all investigators in the field of physiological chemistry.

The present English edition from the latest German one brings the subject down to the most recent date, by permitting the incorporation therein of the results of the latest investigations.

The keynote of the work is struck in the third chapter, on the "Conservation of Energy," from the proper understanding of which the modern study of physiological chemistry must proceed.

The work of Bunge is of the highest order of excellence, and it should have a place in the library of every physician who desires to keep in touch with the cope of scientific investigations, while to the student and investigator it should be wellnigh indispensable. The value of the work to the latter is greatly enhanced by the elaborate system of references to original sources adopted by the author. W.

Alternating Current Machines: Being the second volume of "Dynamo-Electric Machinery;" its construction, design and operation. By Samuel Sheldon, A.M., Ph.D., and Hobart Mason, B.S., E.E. New York: D. Van Nostrand Company; London: Crosby Lockwood & Sons, 1902. (Price, $2.50.)

This work is a companion volume to the work on direct-current machines by the same authors, and like that, is intended as a text-book in technical schools. It treats of the properties of alternating currents; self-induction; capacity; problems in alternating current circuits; alternators; motors; converters; power transmission and tests.

The various types of alternating-current machines described and illustrated are those of American makers. W.

Standard Polyphase Apparatus and Systems. By Maurice A. Oudin, M. S., etc. Third edition revised. 8vo. pp. 289. New York: D. Van Nostrand Company. London: Sampson, Low, Marston & Co., 1902. (Price, $3.)

After defining alternating-current terms, the author treats of generators, induction motors, synchronous motors, rotary converters, static transformers, station equipment and general apparatus; the two-phase, three-phase and monocyclic systems; choice of frequency, the relative weights of copper for various systems, calculation of transmission lines. An appendix treats of the standardization of generators, motors and transformers.

The revision of the third edition appears to have been thoroughly done, bringing the work up to date. The printing and illustration of the work are notably good. W.

Electrical and Magnetic Calculations for the use of electrical engineers and artisans, teachers, students and all others interested in the theory and application of electricity and magnetism. By A. A. Atkinson, M.S. New York: D. Van Nostrand Company, 1902. (Price, $1.50.)

The following subjects are considered: Units and their explanation; relation of quantities; general laws of resistance; electrical energy; alternating currents; wiring for light and power; batteries; magnetism, relation of magnetic quantities; the E.M.F. of dynamos and motors; calculation of fields; elements of dynamo design.

Examples with solutions are given under each subject. The illustrations are numerous and excellent. W.

The Arithmetic of Electrical Measurements with numerous examples, fully worked. By W. R. P Hobbs, R.N. Revised to date by Dr. Richard Wormell, M.A. Ninth edition, small 8vo, pp. 112. London: Thos. Murby; New York: D. Van Nostrand Company, 1902. (Price, 50 cents.)

The arrangement of this booklet is such as should commend it specially to students and those practically engaged in the electrical arts. The fact that it has gone through nine editions would seem to demonstrate its utility.

The work of the present edition has been bestowed principally in the replacing of a number of obsolete or obsolescent terms by their modern equivalents, and the introduction of some explanatory matter, definitions, etc. W.

Historie de l'Observatoire de Paris de sa Fondation á 1793. Par C. Wolf, membre de l'Institut, Astronome honoraire de l'Observatoire. Un volume grand in-8 de xii-392 pages, avec 16 planches. Paris: Gauthier-Villars, 1902. (Price, 15 fr.)

This embraces a history of the matériel and personnel of this famous institution, based upon authentic documents. It is illustrated by an interesting frontispiece and fifteen well-executed plates of plans and elevations of various portions of the buildings. W.

Quelques Reflexions sur le Mécanique suivies d'une première leçon de dynamique. Par Émile Picard, membre de l'Institut. Paris: Gauthier-Villars, 1902. (8vo, pp. 56).

This work is a publication in separate form of a chapter on the principles of mechanics from an official scientific report made by the author on the Universal Exposition of 1900. The chapter is concluded by a primary lesson on kinetics reproduced from the author's lecture-course at the École Centrale des Arts et Manufactures. W.

Die Beobachtungsfehler und die Methode der Kleinstun Quadrate mit ihrer Anwendung auf die Geodäsie und die Wassermessungen. Von Otto Koll, Professor, Geh. Finanzrath im Könl Preuss. Finanzministerium. (Mit in den Text gedruckten Figuren.) Zweite Auflage. Berlin: Julius Springer, 1901.

This work, which is presented in a second edition, treats of the "Errors of Observation" and their various sources, limitations, etc., and of the application of the "Method of Least Squares." W.